Light and Lighting

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Lighting Legislation

UNDER this term a Secretariat Committee of the Commission Internationale de l'Eclairage has just reported on the laws, codes and recommended practices relating to lighting which are current in different countries. There is an important difference of principle in the making of mandatory requirements and of recommended practices for lighting. Statutory requirements are intended to secure for communities what, for the time being, their members regard as minimum rights, e.g., the right to safety and to freedom from exposure to conditions deleterious to health. Recommended practices have a higher aim; they lay down requirements " nearer to the heart's desire " which, if implemented, raise the probability of safety, release more of the individual's potential visual power and so make for greater personal efficiency and a fuller enjoyment of life. Mandatory requirements are much more difficult to alter than are recommendations, and the gap between the respective standards set by statutory regulations and by codes tends to widen as we learn more about what constitutes " good lighting " and revise our codes accordingly. Some such additions to this knowledge are assimilated in the new I.E.S. Code which is reviewed in this number of the Journal.

Notes and News

International Housing

No architect who attends the 1955 Congress of the International Union of Architects (to be held at The Hague next month) should fail to be impressed by the British contribution to the International Exhibition of Housing which will take place there.

The twenty screens of photographs which comprise the British section were on show last month at the Building Centre, London. They provide an excellent cross section of all that is best in post-war British housing.

What these photographs cannot, of course, indicate are the standards of services and equipment of the houses and flats. While in some respects these leave much to be desired (European architects must surely find it incomprehensible that double glazing is, in Britain, generally considered a luxury rather than a necessity), so far as our electric installations are concerned we are way ahead of some, at least, of our European counterparts.

Compare, for instance, our stringent regulations, and our fittings to appropriate standard specifications, with the surface wiring, and switches with an effective life of 12 months or so, to be found in much spectacular Italian housing.

"All that glisters is not gold," and we surely do right to pay as much attention, if not more attention, to things that are hidden in buildings as to things that a camera can see.

R.S.A. Bursaries

We have previously commented on the few candidates who enter for the lighting fitting section of the Royal Society of Arts Industrial Art Bursaries Competition; only six entries were received in each of 1953 and 1954. The standard last year was, in the opinion of the jury, lower than in 1953 and only one prize was awarded. In addition to a set test, candidates have to submit examples of work showing perspective and typical working details for electric light fittings suitable for use in the home (using tungsten lamps), in offices, shops or showroows (using fluorescent lamps). A similar competition, worth £150 as a travelling bursary, is arranged for this year; briefly those between the ages of 17 and 30 who are studying to take up industrial design as a career are eligible. Full details can be obtained from the R.S.A., John Adam Street, W.C.2.

Talking Castles

One of the best lectures given to the I.E.S. for a long time was undoubtedly that by Jean Chappat when he spoke in London about the sound and light festivals at the French chateaux M. Chappat had given the same lecture a few days earlier at Peebles, but there he had been unable to make proper use of his stereophonic sound recordings which were such an impressive feature of the meeting in London.

This lecture is bound to raise once again the question of whether such shows could be put on in this country. We have plenty of historic houses and castles around which a good story could be written; we have the writers, musicians, artists and technicians who could produce such shows and avoid what is vulgar as well as the French have done. The cost of staging these things is high, but experience in France shows that the outlay is soon recovered. Those to whom we have spoken are very lukewarm about the chances of success in this country, but we fail to see why such shows should be a success only in France.

Dow Prize Competition

Though full details are not yet available it is understood that a further I.E.S. competition for the Dow Memorial Prize will be held later this year. Unlike previous competitions this one will not have as its main object the encouragement of collaboration between lighting engineers and some other profession, but will be intended only for lighting engineers with no age restriction.

Entrants will be required to submit an essay of not less than 3,000 words entitled "How I Look at Lighting Engineering." The essays might discuss the author's individual approach to lighting engineering and put forward ideas on the scope and methods of the lighting engineer, supported if necessary by examples of the author's own work. There will probably be three prizes totally not more than £75. Further details of the competition will be announced as they become available.

The idea of such a competition limited to lighting engineers seems quite a good one; the scope is wide

enough to give everyone a chance and should produce some stimulating thoughts on the present state of the art.

We gather that a further collaborative competition is intended for 1957, but in the meantime this year's competition will at least give the lighting engineer a chance to collect the prize money.

Examination Answers

A few years ago we ran a series giving specimen answers to City and Guilds examination questions. This series was primarily for the benefit of students though we believe that many others welcomed the opportunity of brushing up their theory.

We have received a number of requests to repeat this series and we have had the co-operation of Mr. S. S. Beggs, who also produced the original series, who has undertaken to prepare specimen answers to all the questions (intermediate and final papers) set by the City and Guilds this year. The first set of answers appears in this issue; answers to the remaining papers will follow in subsequent issues.

The Name's the Same

Being a little preoccupied at the moment with international matters, we wonder whether anyone has given any thought to the possibility of standardising place names. The following are but a few examples of different spellings for the same place: Basel, Basle, Bale; Cologne, Koln; Coblenz and Koblenz; Prague, Praha, Prag. The alternatives C and K are fairly common and lead to less misunderstanding than many of the other alternative spellings.

Why should places be known other than by the name given them in their own country? Where, for instance, is Londres? That foreigners (including British) have difficulty in twisting their tongues around foreign names is no excuse for changing the name to something they *can* pronounce; they should make the effort. After all, we do *try* to pronounce foreign personal names properly, and we certainly don't change the spelling, at least not intentionally.

Perhaps there is an internationally accepted dictionary of place name spellings, in which case we would be glad to hear of it and to insist on its use; if there isn't one then there jolly well should be.

If you really want to know where Londres is it's in a country called Angleterre, which we can't find in our atlas.

From Miami to Coventry

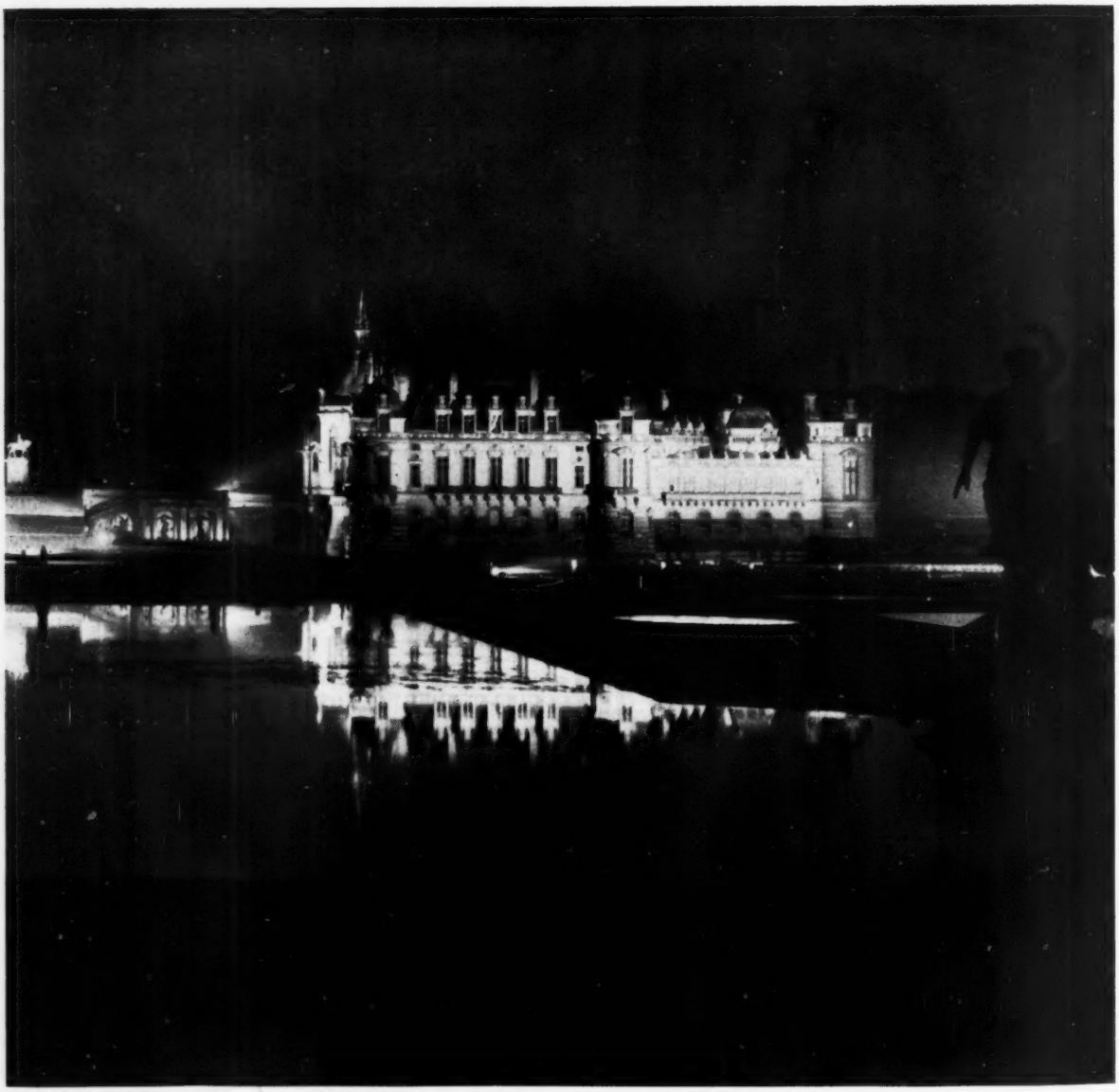
If you work hard for the rest of your life and are careful not to waste money on non-essentials you might with luck be able to afford a holiday at Miami and stay at the Fontainebleau, which we are quite prepared to believe is Miami's "biggest and costliest hotel." (Those of you who get upset at paying more than 15 shillings or so for bed and breakfast should now take a deep breath and prepare to let it out in a long, low whistle.) Prices at the Fontainebleau (600 rooms and suites) range from $33 a day for a room without meals to $185 a day for a suite. (For "a royal suite" you pay a little more; but, of course, if you can afford $185 a day you are presumably able to buy the earth if necessary, and a little more to be royal would be no hardship.)

The designer has gone to town on the lighting, using concealed cold cathode and many varieties of decorative tungsten luminaires, including many chandeliers, one of which is 20 ft. in diameter. It would seem that in some parts of the hotel an attempt has been made to recall the elegance of the French Renaissance and in the lobby objets d'art such as statues, vases and bronzes of that period have been converted into table and standard lamps. You can go and see it for yourself if you like—or you can go to Coventry and see a new hotel in the modern style (see later pages). You'd find Coventry cheaper and a lot more restful.

Zurich Bound

At the time of writing we are about to set out on the railroad to Zurich, the first 60 miles or so of which promise under present circumstances to be the most hazardous. The last couple of weeks or so of coping with London's strike-inflated road traffic are beginning to have their effect on our nerves, and we shall be so relieved when we eventually settle into a comfortable seat on the "Rhinegold" at the Hook on the last and longest leg of the overland journey. (Having mentioned the rail strike, we would apologise for the delay in circulating the June issue, though this was really quite a minor inconvenience.)

By the time this appears we shall have returned from Zurich and will have already embarked on a full report of the proceedings. Judging from the amount of paper which we have already accumulated (about 8 lb. of it so far and still going up), there will be plenty to digest. Some of it we are quite certain we shall never digest; for example, some aspects of lighting provide the mathematicians with a lovely playground, but until such time as they produce something which the architect or lighting engineer can understand and use we can give their masses of formulae and calculations little more than a passing glance. Nevertheless there is plenty of material for us to get on with, and we hope to deal with the reports, papers and discussions fairly fully.



Chateau de Chantilly, the latest addition to the 'talking castles' of France.

The I.E.S. Code for Lighting in Buildings

A detailed review of the new Code which has just been published by the Illuminating Engineering Society.

The last edition of the I.E.S. Code for the Lighting of Building Interiors was issued about six years ago, and since that time Codes have been published in several other countries, notably France and Germany, and the British Code has been widely quoted, e.g., in the American I.E.S. Handbook.

The new edition of the British Code which has just appeared is even more comprehensive than its predecessor, especially in the sections dealing with daylight, and it includes some valuable introductory paragraphs on "Light and Sight." Although it is stated that the Code is "primarily for the reference of those professionally concerned with lighting practice," this introductory part has clearly been drafted to achieve the secondary objective mentioned, viz., "to help users in formulating their lighting requirements." It explains to the layman, in language he can readily understand, the mechanism of seeing and the importance of differences of brightness and colour, the way in which acuity of vision is affected, not only by the luminance of the object looked at but also by that of its surroundings, the importance of glare and the influence of the lighting environment on the feelings of the occupants of a room. This part of the Code forms an excellent basis for the various recommendations which follow later; its inclusion converts what might otherwise appear as a series of more or less *ex cathedra* statements into an orderly and reasoned discussion of good lighting practice, so that the conclusions arrived at are seen to have a logical basis and even a certain degree of inevitability.

The second and third Parts of the Code deal respectively with Artificial Lighting and with Natural Lighting. Although they are of approximately the same length, the part on natural lighting will be dealt with rather more fully in what follows, because this is the first time that this part of the subject has received such a complete treatment in a lighting code and there is consequently more new material here than in the part on artificial lighting, much of which follows lines which are more or less familiar.

Artificial Lighting

The early paragraphs in the Part on Artificial Lighting include the familiar plea for early co-operation between the architect and the lighting engineer, and then follows a list of the headings under which information is required before a lighting scheme can be designed, followed by a paragraph in which are set out the various matters which the lighting engineer must decide on the basis of the information given him. The next section, dealing with the selection and location of sources of light, follows the earlier edition fairly closely, with its schematic table showing the characteristics of the five different types of lighting systems.

The paragraphs dealing with the illumination over restricted areas of special importance and with the relation between general and local illumination have been made more detailed than before and rather more specific, although the numerical values given have not been changed. The sections dealing with the allowance necessary for depreciation in service remains, but a paragraph has been added on the need to allow for the absorption of light under very unfavourable atmospheric conditions.

Glare

The treatment of glare has been much extended and greatly improved. After a series of recommendations in general terms, there are certain specific recommendations, one of which, at least, is novel, viz., that "the average illumination on the horizontal working plane should be at least three times as high as the illumination directly produced by all the visible installed sources on a vertical plane at any occupant's eyes." It should be an interesting exercise for lighting designers of experience to check the validity of this recommendation by measurement on some installations which are known from experience to be satisfactory; probably members of the committee responsible for the drafting of the present Code have already carried out this exercise and have satisfied themselves that it forms a useful working rule.

The table giving the recommended limits for the luminance of sources coming within the normal field of view has been completely re-cast. Instead of relating the values of luminance to the average illumination on the working plane by means of a simple factor depending on the mounting height, the new table gives actual values of luminance, in candelas per square inch, for different mounting heights and different working plane illuminations while, in addition, a distinction is made between large and small fittings (here called luminaires), the

dividing line being at a projected area of 200 sq. in. Speaking in general terms, the present table is not inconsistent with its predecessor but it deals with the limitation of glare in a more logical and workmanlike way and should prove to be a most valuable feature of the Code.

Illumination Scales

The section dealing with the basis and use of the illumination scales has also been rearranged, though much of the description remains as before. Perhaps the most directly valuable part of this section is the now familiar form of illumination chart. This has been adopted in the French Code, it has been reproduced in the American I.E.S. Handbook and it has reappeared in more than one book on illuminating engineering. Although the main part of the chart has not been changed, the method of taking into account the contrast and the "lightness" of the task has been made more definite and clearer in its application; each scale now has printed below it the combinations of contrast and lightness gradings to which it applies, the gradings in each case being "High," "Moderate" (or medium) and "Low." Thus Scale A applies to (i) high lightness with high or medium contrast or (ii) moderate lightness with high contrast, Scale B to (i) high lightness with low contrast, (ii) moderate lightness with medium or low contrast, or (iii) low lightness with high contrast, while Scale C applies only to low lightness with medium or low contrast. "Lightness," it is explained, "means the 'overall' lightness of the object or material within the area containing the contrast presented for discrimination. . . . The overall lightness of a patterned object or material may be regarded as high if it is similar to that of a uniformly coloured object or material having a diffuse reflection factor of not less than 0.45. If the 'equivalent' reflection factor is less than this but not less than 0.2, the lightness is moderate, and for all 'equivalent' reflection factors below 0.2 it is low." This seems admirably clear and should serve to dispel a great deal of the vagueness which hitherto has been associated all too frequently with attempts to allow for this vital factor in assessing the illumination needed for a given task. The size factor was dealt with very well in previous editions and little change has been made here.

Tables of Illumination Values

It is perhaps convenient to refer at this stage to the extensive tables of recommended values of illumination for various purposes and in various locations, although in fact these tables form an appendix to and are printed at the end of the body of the Code. They are generally similar to the tables included in previous editions, but there are some changes which are worth noting. In the first place certain groups of values have been raised, notably in the cases of shops (including restaurants and stores) and libraries; some categories have been rearranged or extended, while a few have been added. An improvement is the removal of the recommendation for "special lighting" in a number of cases and the substitution of a definite (generally high) value of illumination.

Daylight

The Part of the Code dealing with Natural Lighting has been entirely rewritten and extended, and this is a welcome sign of the importance which the Illuminating Engineering Society now attaches to the need for care and skill to ensure that good provision for daylight is made when a building is designed. It has always to be remembered that mistakes in artificial lighting can usually be rectified at not too high a cost and that in any case the system is likely to be redesigned for other reasons within a period of 10, 15 or, at most, 20 years. On the other hand, mistakes made in designing a building, so that the daylight provided is inadequate, generally cannot be rectified without very costly structural alterations, and so their effects may well last as long as the building itself.

The 11 or so pages devoted to daylight in the present edition of the Code have obviously been written by someone fully cognisant of the need to help the building designer (generally an architect), and the treatment is such as to appeal to him and enable him to obtain the guidance he needs, without having to familiarise himself with all the nomenclature and methods of design used by the illuminating engineer in his day-to-day work on artificial lighting. As stated in the introduction to this Part, the treatment is rather more detailed than in the Part dealing with artificial lighting, partly to compensate for the relative scarcity of literature on natural lighting.

There is first a useful section on the basic concepts underlying the computation of sky factors and daylight factors, while the important part played by reflected light, both from internal surfaces and from the surfaces of external objects, is carefully explained. Next there is a section on the distribution of light, and a good example of the method used throughout this part of the Code is furnished by the opening sentence in this section, which reads as follows: "One criterion of successful lighting is to have the things one wants to look at as bright or brighter than anything else in the field of view, for when this is the case they form a natural, effortless focus of attention, and the eyes will generally be put into a favourable state of adaptation." Later it is pointed out that there are two classes of interior, one in which the occupants are free to change their positions so as to make the best use of the daylight available, the other in which they are not and in which, therefore, all working positions must be adequately provided with daylight and the design of the building considered with this in mind.

There is then a section, over two pages in length, dealing with reflected light and the different ways in which this can be utilised to improve lighting conditions, especially in rooms lit from a side wall. It is pointed out that in such buildings as factories, walls are generally remote from the work, while the ceiling is not of much value as a reflector and it is therefore not often possible to depend on reflected light to assist in the illumination of the working plane by daylight. This, however, is not the only function of reflected light and its use in providing natural modelling of objects and in providing a pleasant appearance is mentioned. This section concludes with the statement, "The fact is that a room with good reflected light will generally appear to be a better lighted space than, for example, the same space with much higher levels [of illumination] and poor reflection."

The next section deals with the all-important matters of the location of openings and their design so as to achieve the objectives described in the previous sections. Windows in one side of a room are condemned on the ground that the distribution of light is bad, with excessive

high lights and shadows; lighting from two adjacent sides is considered preferable. Lighting from two opposite sides again creates difficulties due to glare unless one of the windows is a clerestory. Top lighting is treated at some length, and the fact that a large number of small lights gives a better distribution than large lights too widely spaced is pointed out. Saw-tooth roofs are condemned as leading to strong shadows and poor modelling.

The design of windows comes next and the relative advantages of the high window and the long narrow window are stated. There is a lengthy discussion of the danger of glare due to excessive contrasts and different ways of reducing such contrasts are listed. The subject of glare by unobstructed windows is considered important enough to justify the inclusion of a table giving the degree of glare discomfort likely to be experienced, in a room of average reflection characteristics, under different sky conditions when the windows are of such a size that one-fifth or more of the visual field is occupied by a direct view of the sky. This is immediately followed by a short section on the desirability of a proper balance between the brightness of the sky and that of the interior and it is mentioned that in side-lit rooms supplementary artificial lighting may be necessary to reduce glare as well as to add to the illumination on the working plane.

Daylight Recommendations

The final section of this part of the Code contains a series of very important recommendations. As far as daylight factors are concerned there is first a table showing, in effect, the recommendations in the 1944 "Report on the Lighting of Buildings" for the area and depth of penetration of selected daylight factors in the different rooms of a dwelling house. For schools the recommendation is for a minimum of 2 per cent. on the working plane in all teaching accommodation and in kitchens. Then follow recommendations for offices and drawing offices which, again, are the same as those made in the 1952 "Report on the Lighting of Office Buildings." Finally there is a recommendation that, for the sake of amenity alone, a minimum daylight factor of 0.5 per cent. should be provided over at least half the floor area in any room. This recommendation is continued from the earlier edition of the Code and so is the recommendation regarding the angle of elevation of the window-head, although this angle has been reduced from 24 deg. to 20 deg. The grounds on which this reduction has been made are not clear and the accompanying footnote that "the height of the window head above the working plane is then slightly less than half the distance of the point from the window" might well be reworded to read "slightly more than one-third" instead of less than one-half. There is a useful caution about the use of glass blocks and prismatic or diffusing glass, while the final paragraph in this section deals with the use of artificial light for supplementing daylight in cases where the illumination required is more than can be provided except for comparatively short periods during the working day.

The Scientific Basis

There are now three Appendices to the Code. The first consists, as before, of the "Schedule of Recommended Values of Illumination on objects of special regard in various interiors or occupations." The second is new and is headed "Documentation." It is introduced with a sentence which is worth quoting and which it is to be hoped will be noted by every user of the Code, viz., "The statements and recommendations in this Code are founded upon the general physiology and psychology of vision, and upon the applied science of lighting and seeing which has grown out of numerous special studies and investigations made in this and other countries, particularly during the past few decades." It is not uncommon to find among otherwise intelligent engineers an impression that a lighting code is the product of informed guesswork on the part of lighting engineers, in fact only one stage removed from a combined effort to "think of a number." Readers of *Light and Lighting* are well aware that while this might have had some truth in it when the early codes were being produced, to-day the situation is altogether different. It is as well, therefore, that the sentence quoted above also appears in heavy type in the preface to the Code, where anyone taking up the Code cannot fail to have his attention drawn to it.

This Appendix contains an impressive list of books and of scientific and technical papers and reports dealing both with basic principles and with specific matters dealt with in the Code, and it should convince the most sceptical that the recommendations made are backed by a wealth of research and experiment of a high standard.

The third Appendix contains, as before, a list of relevant British Standards.

It has already been mentioned that the present edition of the Code is considerably longer than its predecessor. For this reason the absence of an index is more likely to be felt. There is, however, a detailed table of contents, and with this the user must be satisfied at the present stage. If, however, the Code continues to grow as further editions are called for, the provision of an adequate index will become a necessity.

Conclusion

To sum up, it may be said that a comparison of this edition of the Code with that of 1949 leaves the impression that everything of most value in the latter has been retained. In particular, the values of illumination recommended have, with very few exceptions, been confirmed, a cogent reply to those who have said that every lighting code prescribes higher values of illumination than the one before it. At the same time, in many places the treatment has been greatly improved, the recommendations are made clearer or more specific, while the section on natural lighting is now developed so that it should be of great value to everyone concerned with the design of buildings. The production is very attractive and the price (5s.) moderate.

B.S.S. on Parking Lights

To coincide with the Ministry of Transport's recent announcement of concessions which allow the parking of vehicles after dark without normal lights, the British Standards Institution has just published a new specification, B.S.2605, "Parking lights for vehicles." The principal basis of the new standard is a series of tests to ensure that parking lights offered for sale will be durable and will give adequate light for the purpose. Parking lights which successfully pass these tests and thereby meet the requirements of the British Standard, will be marked with the standard number, i.e., B.S.2605, for the information of purchasers. Copies may be bought, price 2s. 6d. post free, from the B.S.I., British Standards House, 2, Park Street, London, W.1.

Lighting Codes

By H. C. WESTON

A discussion of the similarities and differences between the British I.E.S. Code and codes published in other countries.

The subject of lighting codes has been under discussion at the meetings of the International Illumination Commission in Zurich, which were concluded on June 22, and a new version of the British I.E.S. Code was published in the previous month. No official report of the Zurich discussions is likely to be published for some time yet, but it seems opportune at present to discuss the similarities and differences between the British Code and some of the corresponding publications in other countries. It is sometimes asked why different values of illumination are recommended for apparently similar purposes in different codes, and one of the principal objects of this article is to examine such differences and explain them.

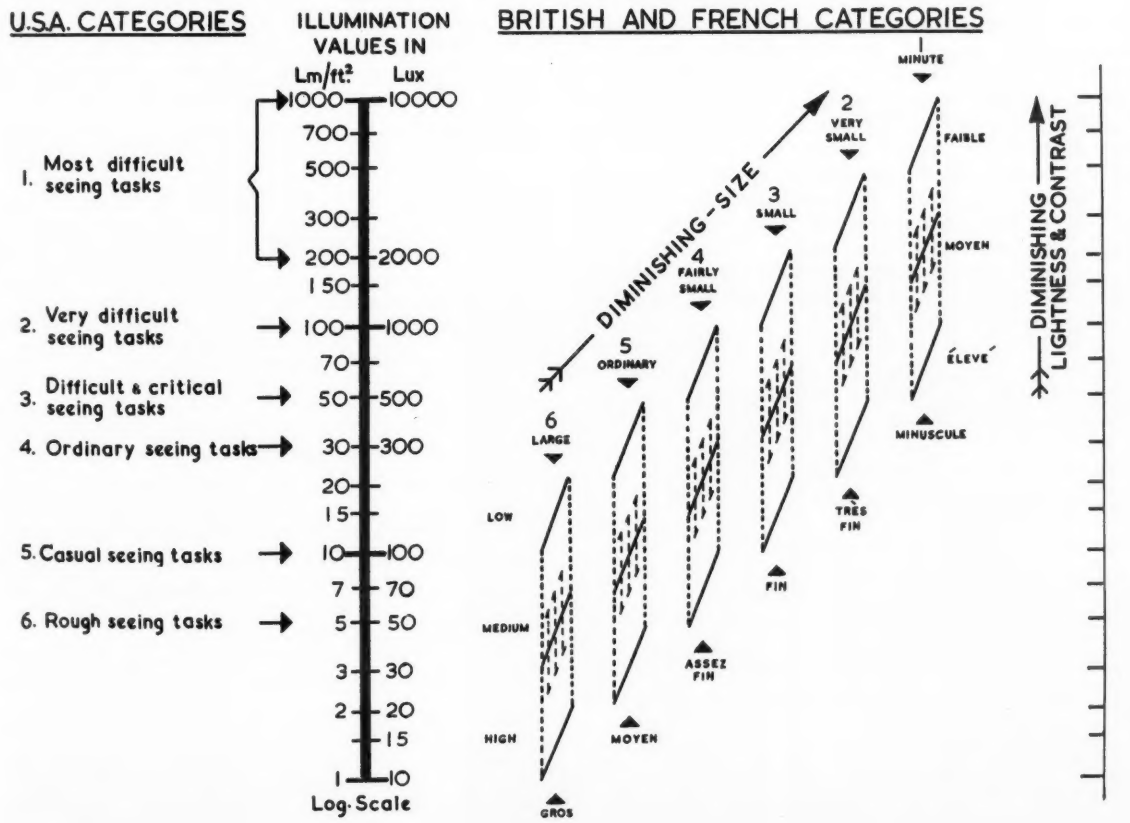
In the first place, however, a few general remarks about codes are desirable. Whatever the subject with which it deals, a code is not a treatise or text-book, although lighting codes do differ in the amount of explanatory matter they contain. A code is concerned with broad principles and with limits and tolerances to be observed in the practical application of the principles, but it should not be so detailed as to restrict design unnecessarily and lead to stereotyped practice. Lighting codes issued by technical bodies such as the I.E.S. or by the B.S.I. have no mandatory force, but, of course, compliance with their recommendations can always be insisted upon by users of lighting, who can, if they wish, specifically require such compliance when contracting for new installations.

Plato remarked that "the sense of sight is most acute in us." This is true, but we only have the most acute sight in the most favourable circumstances, that is when the prevailing illumination is as liberal as Nature provides outdoors during some part of nearly every day, and which is so high as almost never to be found indoors either by natural or by artificial lighting. Everyone knows that sight is not so acute at much lower levels of illumination. Just how much such levels lower our visual acuity has been known for many years. For example, at 4 lm/ft^2—a value near the lower extremity of the I.E.S. Code range, and actually just below the recommended illumination for the lowest category of visual tasks considered in the American Code and in the Dutch (Philips) recommendations—the acuteness of sight amounts to only half its physiological maximum. It would be quite naive to imagine that in order to double this acuity, i.e., to get the most acute sight, all that is necessary is to double the illumination that gives half acuteness. In fact, large increments of illumination are necessary to get small increments of visual acuity, and instead of increasing our 4 lm/ft^2 by a factor of 2, it needs to be increased by a factor of about 200 x 2 before we have enough illumination for the most acute sight! In other words, it is known, from actual measurements, that for maximum visual acuity an illumination of more than 1,000 lm/ft^2 is required. It is not therefore surprising that in contemporary lighting codes, e.g., the British, French and American codes, which are based on the science of light and sight, the scale of recommended values of illumination extends as far as 1,000 lm/ft^2. This is only different from earlier codes which recommended, for the most difficult visual tasks, an illumination of "above 50 lm/ft^2" (I.E.S. Code, 1942) or "more than 1,000 lux" (Holland) in that it is more specific and less timid.

Visual power varies with the amount of illumination in such a way that when considering discrepant recommended values what matters is not the arithmetic difference between them but the ratio in which they stand. The standard of relative visual performance (i.e., percentage of the average person's possible maximum performance of different grades of visual task) which is taken as the criterion for the I.E.S. values is sufficiently high for these values to be located on that portion of the performance v. illumination curve which has only a slight slope. This means that if a higher standard of performance is aimed at a gain of 2 or 3 per cent. can be got only if the I.E.S. values are increased by a factor of 2 or 3, i.e., if they are doubled or trebled. So, if one country recommends for a given "task" twice the illumination recommended by the I.E.S. the discrepancy between the two codes is not so great as to undermine confidence in either because, in fact, such a discrepancy means no more than that one country is "legislating" for a slightly higher standard of visual performance than the I.E.S. is. Similarly, of course, a country which recommends only half the illumination recommended by the I.E.S. Code for a given task is simply "legislating" for a somewhat lower standard of performance. However, the loss in such a case will be proportionally greater than the gain got by doubling the I.E.S. value, since the lower value will be located on the performance v. illumination curve where it is sloping fairly steeply downward. Discrepancies between I.E.S. values and their "opposite numbers" in other codes are insignificant where they do not exceed 10 per cent. and are of small consequence if they are as

much as 20 or 25 per cent. If "relative visual performance" is the criterion taken for recommending values of illumination in different countries, the standard adopted may be related to the national economics of lighting, if desired. This was pointed out by Dr. N. A. Halbertsma in an address to the I.E.S. in 1947. Referring to the criterion "relative performance" introduced by the present writer, Dr. Halbertsma said, "It has become possible to establish a number of lists of recommended illumination values each based on a different 'relative performance,' say 95 per cent., 90 per cent., 85 per cent., 80 per cent. This would correspond to a classification of such lists, the first one with 95 per cent. relative performance providing 'very best' lighting, the one with 90 per cent., very good lighting, the one with 85 per cent., reasonable lighting. Any country might then select that list which corresponds to the class of lighting it can afford to have from an economic point of view." Whether or not this criterion is deliberately taken—and it is now favoured in several countries—different scales of recommended values do imply different results, including different standards of visual performance.

The method classifying seeing tasks in the British and the French codes differs from the method used in the American and other codes, and it is to this difference of method that some apparent discrepancies in recommended values of illumination are due. In 1945, for the first time, a new method of classification based on the size, lightness (of colour) and contrast of the objects requiring to be seen was used in the British code and was subsequently adopted in the French code. According to this method the whole range of sizes to be catered for is divided into six categories, and the full range of lightness and of possible contrast is divided into three broad categories, one of each for each grade of size. Three suitable ranges of illumination values are recommended for each size category, one for each range of lightness and contrast in which that size may be encountered. This makes the full range of values for each category of size (i.e., "fineness") very wide; in fact, the maximum and minimum values for each size category (which, of course, includes more than a single size) are in the ratio of about 20 to 1 (strictly, 21.54:1). This method of classification and specification of illumination values, which has emerged from the proposals for an analytical code put forward more than 20 years ago by Beuttell and from the subsequent proposals of Weston, who determined the relation between illumination and the variables size, lightness and contrast with respect to visual performance, is therefore objective, analytic and quantitative, whereas the method formerly used, and still retained in the American and some other codes, is subjective and qualitative, i.e., seeing tasks are classified as "most difficult," "very difficult," "ordinary" (i.e., of ordinary difficulty), and so on. Now, according to the British and French codes, tasks involving objects of minute size require from 50 to 1,000 lm/ft² according to the lightness and contrast of the objects. Some of such tasks are those classified according to the American code as "most difficult seeing tasks," for which that code recommends 200 to 1,000 lm/ft², while others are those



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classified as "very difficult seeing tasks," for which 100 lm/ft² is recommended in the American code. How the British categories overlap the American is shown by the accompanying diagram. It will be seen that a similar range of visual tasks is covered by a similar total range of recommended illumination values in each code. However, differences are to be found between the values recommended for some apparently equivalent specific tasks which are scheduled in the respective codes. There are various reasons for these differences, some of which have been indicated already. Where differences do exist the American values are generally higher than the British. The chief reason for this is the American view that it is economically worth while to use higher values of illumination in order to secure a somewhat higher standard of visual efficiency and a more generous "factor of safety" against the occurrence of visual stress and discomfort. It has been pointed out already that getting a slightly better standard of visual performance than is provided for by the British code means using a lot more light. To take an example, the British code recommends 10 lm/ft² for "ordinary" inspection work, while the American code recommends 20 lm/ft² for "rough" (= ordinary) inspection. In this instance neither value is very high, and either can be had at reasonable cost. For all finer grades of inspection, which require substantially higher values of illumination, the recommended values in the two codes are identical. As representative of the greatest of the discrepancies between the scheduled values in the two codes, we may take the values recommended for "cutting, fleshing and stuffing" in leather manufacturing. The British code suggests 5 lm/ft² and the American code gives 20 lm/ft². Remembering what has been said about how large a step up the illumination scale must be made to get a worthwhile return after reaching the point at which—for a given type of task—"the law of diminishing returns" comes into operation, even this relatively large difference is much less startling than it is apt to appear at first sight. However, the operations cited may not be identical in the two countries even though they go by the same name, but, assuming they do not differ, the evaluation of the lighting requirements may be better in one country than in the other. In no country have *all* the scheduled tasks been unequivocally evaluated as to the illumination they need—this is itself an immense task and, just because more needs to be known about some tasks, codes are revised from time to time so that better estimates of their requirements can be included. However, large differences between values of illumination recommended in different codes for what seems to be the same purpose are rare. They do, however, suggest the need for further investigation, but, meanwhile, no one will go far wrong by steering a middle course—using in practice the geometric mean of the discordant recommended values.

As to features other than illumination itself which affect the revealing properties of lighting, and are necessary to prevent discomfort of the user, the recommendations of contemporary codes are in very fair agreement. Here again, however, American recommendations appear to be rather more exacting than are the British as regards maximum luminance of luminaires. This is probably desirable in view of the tendency in the United States to use somewhat higher values of illumination for general lighting than are accepted in European countries as sufficiently good practice.

Lighting Abstracts

For the benefit of those wishing to obtain articles mentioned in "Lighting Abstracts" the following list gives the full title of journals referred to and the addresses at which they are published. The addresses given are believed to be correct but no guarantee in this respect can be given.

All articles or papers abstracted are understood to be generally available. Unless otherwise stated in the abstract the language in which the article or paper is written is English.

Copies of articles or papers cannot be supplied from the offices of *Light and Lighting*.

Bull. Soc. Franç. Elect.	*Bulletin de la Société Française des Electriciens*, 8-14, Avenue Pierre Larouse, Malakoff (Seine), France.
Bull. Assoc. Suisse Elect.	*Bulletin de l'Association Suisse des Electriciens*, Seefeldstrasse 301, Zürich 8, Switzerland.
Byggmästaren	*Byggmästaren*, Kungsgatan 32, Stockholm, Sweden.
Electrical Construction and Maintenance	*Electrical Construction and Maintenance*, 330, West 42nd Street, New York 36, New York, U.S.A.
Elektro-Post	*Die Elektro-Post*. Verlagsort (13b), Mindelheim, Germany.
Elektrotech. Zeits. (B)	*Elektrotechnische Zeitschrift (Ausgabe B)*, Brillerstrasse 99, Wuppertal - Elberfeld, Germany.
Elettrotecnica	*Elettrotecnica*, Associazione Elettrotecnica Italiana, Via S. Paolo 10, Milan, Italy.
Illum. Engng.	*Illuminating Engineering*, The Illuminating Engineering Society, 1860, Broadway, New York 23, New York, U.S.A.
Int. Ltg. Rev.	*International Lighting Review*, P.O. Box 7048, Amsterdam, Netherlands.
J. Opt. Soc. Am.	*Journal of the Optical Society of America*, American Institute of Physics, 57, East 55th Street, New York 22, New York, U.S.A.
Lichttechnik	*Lichttechnik*, Eichborndamm 141-167, Berlin-Borsigwalde, Germany.
Ljuskultur	*Ljuskultur*, Sveavagen 28-30, Stockholm, Sweden.
Lux	*Lux*, 108, Rue Denfort Rochereau, Paris (VIIIe), France.
Philips Res. Rep.	*Philips Research Reports*, Century House, Shaftesbury Avenue, London, W.C.2.
Rev. gen. Elect.	*Revue Générale d'Electricite*, 12, Place Henri-Bergson, Paris (VIIIe), France.
Trans. Illum. Eng. Soc. (London)	*Transactions of the Illuminating Engineering Society*, The Illuminating Engineering Society, 32, Victoria Street, London, S.W.1.
Trans. S. African Inst. Elect. Engrs.	*Transactions of the South African Institute of Electrical Engineers*, Kelvin House, Marshall and Holland Streets [P.O. Box 5907], Johannesburg, South Africa.

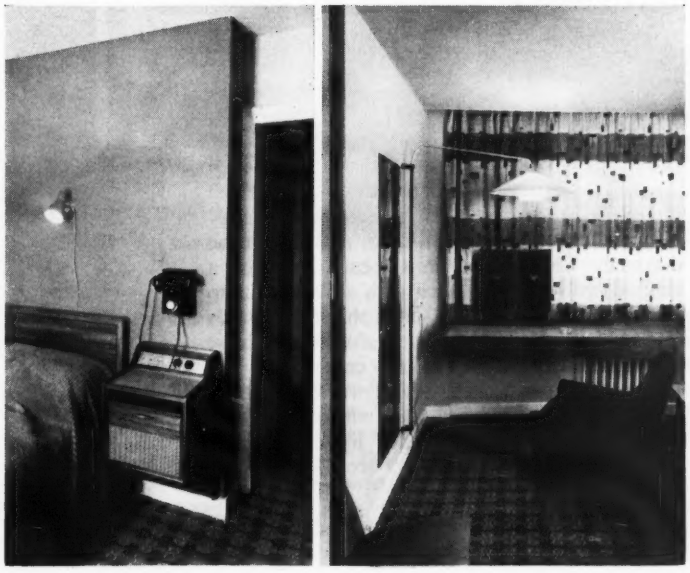
Hotel Leofric
Coventry

Architects: W. S. Hatrell & Partners, in collaboration with W. J. Witham, A.R.I.B.A., chief architect, Ind Coope & Allsopp, Ltd. General contractor, Sir Robert McAlpine & Sons, Ltd.; consultants for electrical installation, Sir Robert McAlpine & Sons, Ltd.; electric wiring, Troughton & Young, Ltd.; light fittings, Troughton & Young (Lighting) Ltd.; main switchgear, Bill Switchgear, Ltd.; other switches, Walsall Conduits, Ltd.

Britain's largest post-war hotel, the Leofric, forms part of the planned redevelopment of Coventry's blitzed central area. There are 108 bedrooms, over 70 with private bathrooms, plus 30 bedrooms for resident staff. The seven-storey building has a reinforced concrete frame. External walls and most internal partitions are of brick. Columns are faced externally with Travertine marble and Westmorland slate. Floors and roof are of *in situ* concrete. The roof over the ballroom is of steel decking on steel trusses. Central heating is by means of hot water from three oil-burning, cast-iron, sectional boilers. Most of the public rooms and all the bathrooms have an air-extraction system. The hotel was constructed in 17 months.

BEDROOMS

Most furniture built-in; each bedroom has its own decoration scheme, usually with two painted walls (different colours) and one wall covered with wallpaper or Vynide; aluminium sash windows, without glazing bars, give view of Precinct.



Each bedroom has a swivel-type wall bracket fitting; this is a stock fitting with special finishes (e.g., the standard is covered with green leather) and with the addition of a handle with which to move it. There is also a small wall fitting (a spun-brass reflector on a knuckle joint) over the bed. All lights in each bedroom or suite are controlled by two groups of switches—one by the bed, one by the entrance door. The electrical installation also includes sockets for dry shavers of various voltages, and built-in lighting to the writing-desk and cocktail cabinet, which switches on and off automatically as the fitting is opened or closed.

LOUNGE

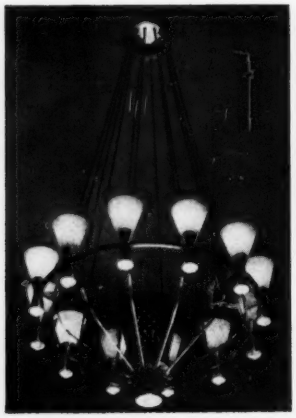
Finishes include extensive use of polished Australian walnut; specially designed carpet (used throughout hotel) is red, grey and yellow.

Lounge has floor-to-ceiling windows giving access to continuous balcony overlooking Precinct area and, when it is built, the new cathedral. Lighting is by means of special ceiling fittings with red and white silk shades and gilt bosses. **Reception area** (seen in background of photo) is lit by small (24-volt) pearl lamps recessed into acoustic ceiling.

FRENCH RESTAURANT

Leads off lounge and also has floor-to-ceiling windows, giving access to balcony; one entire wall faced with black mirror-glass to give impression of increased depth.

Lit mainly by 24-volt pearl lamps (as used for motor-car headlamps), recessed into dark-blue ceiling. Since photo was taken, rows of pendant fittings have been added to give extra illumination when required.



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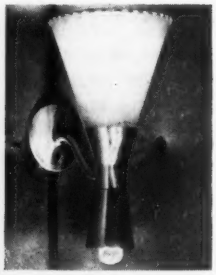


2

3

BALLROOM

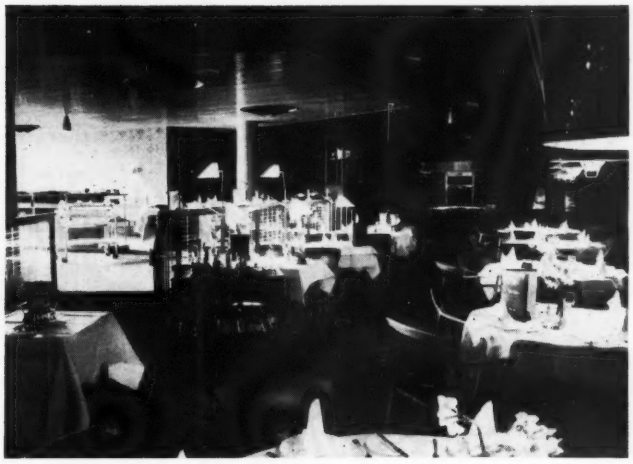
Provides accommodation for 600 dancers or 500 diners; finishes include variety of timbers, some perforated with decorative patterns; balcony at one side is backed with red leather-cloth over sponge rubber. There is a sprung floor and an air-extraction system.

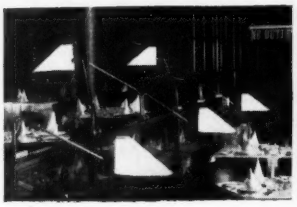
Large laylight of Plyglass conceals two sets of stage battens, with automatic colour-change and dimming apparatus. There are six specially designed chandeliers, which can also be dimmed. The chandeliers **(1)** each comprise a ring of twelve fittings, each with a 60-watt lamp enclosed in a red leather shade shining upwards and a 15-watt lamp in a spun aluminium shade shining downwards. In the centre is a red perforated metal shade which revolves, containing a 100-watt lamp, below which is a lamp connected to the emergency lighting system. Wall lights **(2)** on the balcony are similar to the components of the chandeliers. Partially recessed into the underside of the balcony are special circular fittings **(3)**.

SILVER GRILL

Restaurant on two levels with floor for dancing. Cooking of grills takes place in restaurant, which has air-extraction system.

This restaurant is lit mainly by fittings on the tables, and a network of special fittings **(1)** (with standard shades) along the balustrade between the two levels of the room. These latter fittings light two rows of tables—one at the higher level, one at the lower level. There are also some wall lights and a row of rise-and-fall pendant fittings **(2)** over the tables farthest from the windows. These are raised when this part of the restaurant is used for dancing.





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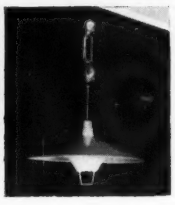
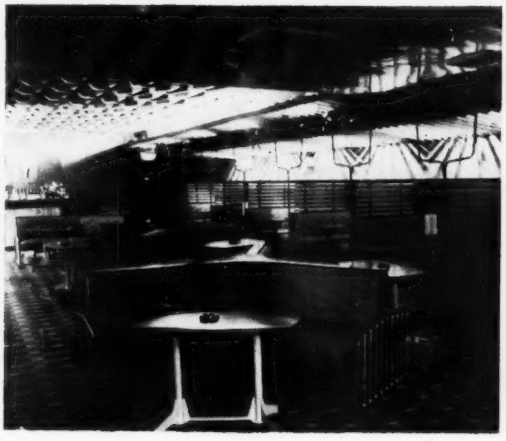


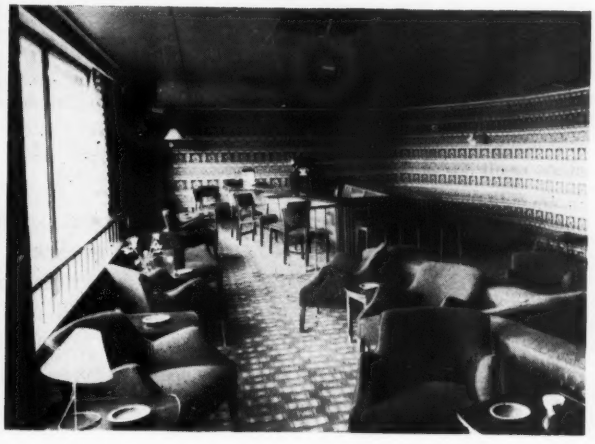
2

COCKTAIL BAR AND PRECINCT BAR

Cocktail bar has walls of walnut, and of sponge rubber, with pattern giving appearance of tapestry; ceiling of sky-blue acoustic tiles. Precinct bar has floor of plastic tiles; walls partly covered with imitation lizard skin Vynide; has entrance direct from street.

The cocktail bar is lit mainly by "overflow" lighting from the central bar, where strip lights are placed below counter level. There are also a number of wall fittings and table lamps. The Precinct bar is lit mainly by reflected light from the contemporary-style coffered ceiling, the light coming from spotlight fittings on one side.





THE INSTALLATION.—From the main switchboard, feeder ducts carry the supply to distribution boards on each of the bedroom floors, with separate feeder mains carrying power to equipment in the kitchen, boiler house, and laundry, and for the ventilation system, lifts, water-booster pumps, floodlighting and neon signs. Wiring comprises V.I.R. conductors in conduit. Power supply: 415/240-volt, three-phase, four-wire A.C. for motive power; 240-volt, single-phase A.C. for lighting and socket outlets; 24-volt D.C. for "starlighting" in ceilings; 12-volt D.C. for signal systems. A secondary lighting system (110-volt D.C.), incorporating a battery and emergency equipment, is provided for all main corridors and staircases; it feeds approximately 130 points. Outside the building, provision is made for floodlighting and for various neon signs. Special light fittings were designed by Troughton and Young (Lighting), Ltd., in close co-operation with the architects.

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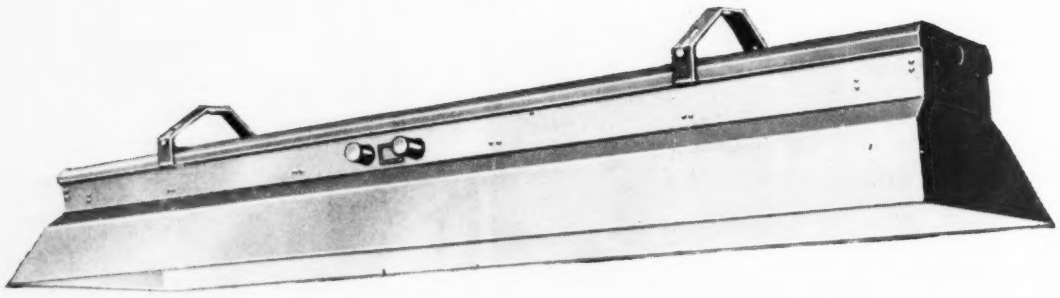

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Smee's 2

A Method of Designing Symmetrical Specular Reflectors for Small Light Sources

A graphical method is described for the design of symmetrical specular reflectors for small light sources by which the "reflecting scheme" may be drawn up without calculation and the contour plotted in only a fraction of the time required by previous methods.

By J. A. LYNES, B.Sc. (Eng.)*

Well-established techniques exist for the design of symmetrical specular reflectors which will provide a required distribution of light. These methods generally involve the determination of the light flux in each zone of the polar curve of the bare lamp, and in each zone of the polar distribution required; the reflector contour is then set out, which will redirect the available bare lamp lumens out of the zones in which they are not required, and into the zones into which the light is required. The correct amounts of light must, of course, be reflected into each zone, and due allowance must be made for losses on reflection, etc.

Existing Methods

Halbertsma's method[1][2] involves dividing a Rousseau diagram into strips of equal area. This is accomplished by a process of trial-and-error, and would be rather difficult to achieve in practice.

The method described by Jolley, Waldram and Wilson[3] is more straightforward, but involves rather tedious calculation.

The flux in each 10 deg. zone of the bare lamp must be computed by multiplying the mean intensity in each zone by the corresponding zone factor. The reflected flux is multiplied by an appropriate constant in order to allow for the loss of light on reflection, etc. Running totals of bare lamp flux and of reflected flux may then be tabulated.

The mean intensity in each zone of the required light distribution must be multiplied by the corresponding zone factor in order to obtain a running total of the flux required in each zone. These running totals must be multiplied by a constant, so as to ensure that the total light flux required is equal to the total light flux available. The light flux which must be redirected into each zone by the reflector is determined by subtracting the direct contribution of the bare lamp from the total lumens required in each zone.

Finally, by drawing a suitable graph of the lumens available for reflection, and of the redirected lumens, it is possible to determine the direction in which each portion of the bare lamp flux must be redirected. The required reflector profile may then be constructed.

The mathematical procedure outlined above may be entirely replaced by the use of a geometrical construction which will now be illustrated by means of an example.

Representation of Bare Lamp Flux

Figs. 1 and 2 show respectively the polar curves of the bare lamp and the required light distribution. Both have been deliberately plotted to arbitrary scales, since the magnitudes of the intensities involved do not affect the final profile of the reflector.†

Horizontal lines are drawn on each of these polar curves, connecting the end of the intensity vector at the mid-point of each 10 deg. zone with the vertical axis of the light distribution curve. This may be readily accomplished by the use of a tee-square. The length of each of these horizontal lines is $I_\theta \sin\theta$, and their length may be regarded as proportional to the light flux F in the corresponding zone, since

$$F = 2\pi \int_{\theta_1}^{\theta_2} I_\theta \sin\theta \, d\theta$$

where θ is the angle between the intensity vector and the downward vertical, I_θ is the intensity at the angle θ, and θ_1 and θ_2 are the limiting angles of each zone. This method of representing the flux in each zone is due to A. A. Wohlauer[5].

Procedure

"Step off" each of these horizontal lines by means of a pair of dividers. Set them in a straight line, end to

* Falk, Stadelmann and Co. Ltd.

† The "required distribution" selected for this example is based upon a theoretically desirable curve for a spacing-height ratio not exceeding 1.5 : 1(4).

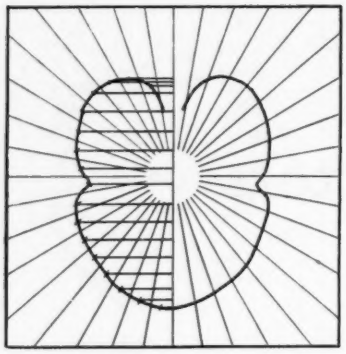

Fig. 1. Polar curve of bare lamp

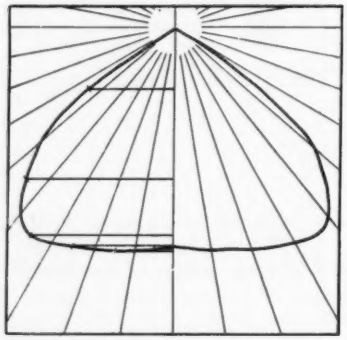

Fig. 2. Required polar distribution

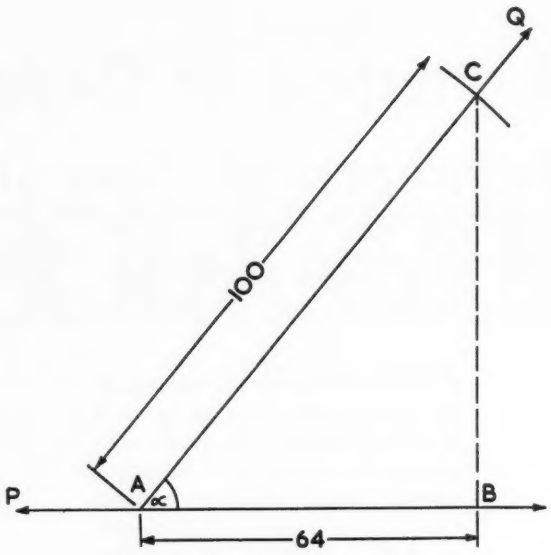

Fig. 4. Construction of angle α.

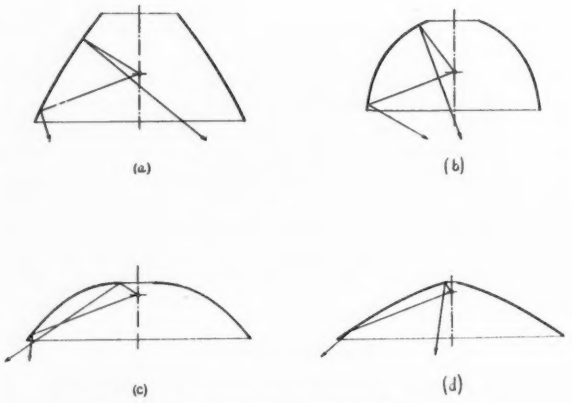

Fig. 5. Four possible reflector arrangements

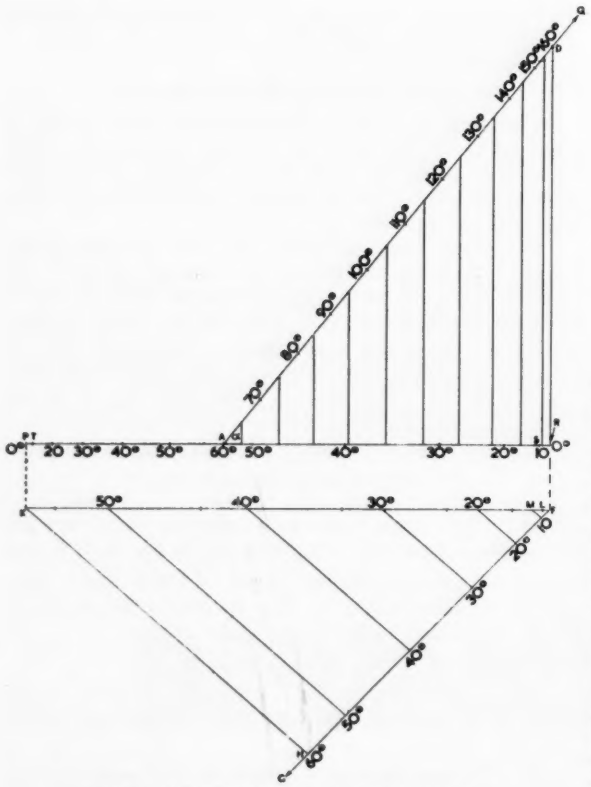

Fig. 3. Construction for flux redistribution

end, from left to right, in the manner shown in Fig. 3, starting from the point P with the 0-10 deg. zone of the bare lamp, and taking care to mark on the drawing the values of the limiting angles of each zone. Continue this procedure until the angle of cut-off (60 deg. in this example) is reached. At this point let the line be turned through an angle α, such that cos α is equal to the proportion of the light incident on the reflector which will be available for redistribution. For example, if the specular reflection factor is 0.8, and if a further 20 per cent. loss occurs through such causes as absorption of reflected light by the lamp bulb, then $\cos \alpha = 0.64$.

The geometrical method of constructing this angle is shown in Fig. 4. Mark off a distance AB, along the line PA produced, such that AB = 64 units. Erect a perpendicular on B, and strike an arc, with centre at A, and radius 100 units, to intersect the perpendicular at C. BAC will be the required angle α. Now mark off the

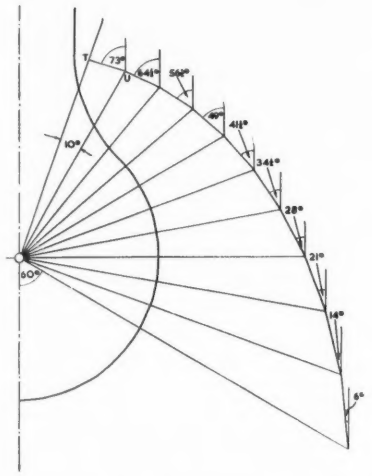

Fig. 6. Setting out the reflector contour

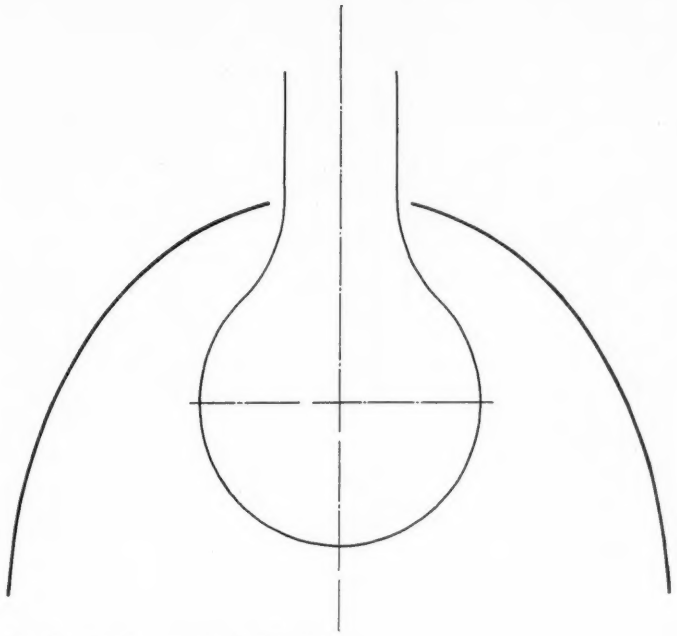

Fig. 7. Final contour of reflector

bare lamp flux from the zones between 60 deg. and 160 deg. along the line AQ. Bare lamp flux above 160 deg. should not be shown, as it is assumed to be lost through the neck of the reflector.

Distribution of Reflected Flux

In general there are four possible methods of construction for a specular reflector which will provide a given light distribution. These four arrangements are shown in Fig. 5. Their respective merits have been discussed elsewhere[1] [3]; for this example, type (b) will be adopted.

Mark the point F on the drawing paper, some distance vertically below the point D, as shown in Fig. 3. Through it draw a straight line FG, suitably inclined to the horizontal (an angle of 30 deg. is often convenient, but a larger angle would be equally satisfactory—the final decision may depend upon the shape of the drawing paper.) Starting from the point F with the 0-10 deg. zone, plot the light flux for the required distribution along the line FG, in a similar manner to that described above for the bare lamp flux. The last point to be plotted in this example will thus be the point H, representing the 60 deg. extremity of the 50-60 deg. zone of the reflector, i.e., the cut-off angle.

Draw a line FK horizontally through F, such that the point K is vertically below the point P; join HK. Lines may now be drawn, by means of an adjustable set-square, parallel to HK, connecting points on the line FH to corresponding points on the line FK, as shown in the figure.

The line FK now represents the required flux distribution, drawn to the same scale as the lines PA and AD. At this point it is necessary to subtract from the required distribution the contribution of direct light flux from the bare lamp. This must be done separately for each zone, starting from the 0-10 deg. zone. Thus the length FL, equal to the length PT, should be stepped off by means of a pair of dividers; the length LM now represents the amount of light flux which is to be redirected by the reflector into the 0-10 deg. zone. The same method is used for finding how much light flux must be redirected into each of the other zones.

Mark the point R on the line PA produced, vertically below D, as shown in the figure. Along this line step off the length RS equal to LM. Corresponding lengths should be stepped off for the other zones, each length representing the lumens which must be redirected into that zone. If the construction has been carried out correctly the 60 deg. extremity of the 50-60 deg. zone should coincide with the point A. (The above instructions apply only to reflector arrangements (b) and (d) in Fig. 5. If arrangements (a) or (c) are adopted, the length equal to RS should have been stepped off from left to right, starting at A, instead of right to left, starting from R. Corresponding lengths for other zones should be set from left to right, too.)

The next step is to discover over what angles light must be collected for redistribution between other angles. This may be done by dropping perpendiculars, from the mid-points of each 10 deg. zone along AD, on to the line RA. The point, on the angle scale of RA, in which each of these perpendiculars meets the line RA, is the angle, measured from the downward vertical, into which the mid-zone ray is to be redirected.

Table I may now be drawn up; it should be considered in conjunction with Fig. 8. The first column of Table I shows the limits of each zone in which the flux to be redistributed is emitted from the lamp. The second column shows the mid-point angle (θ) of each of these zones. The third column shows the angle (δ), measured from the downward vertical, into which each of the mid-zone rays is to be redirected. The fourth column shows the inclination (ϕ) of the corresponding reflector element to the

TABLE 1
REFLECTING SCHEME.

Zone in which light is emitted from lamp		Angle into which light must be redirected δ	Inclination of reflector element to vertical $\phi = \frac{\theta - \delta}{2}$
Limits of zone (degrees)	Mid-zone angle θ (degrees)	(degrees)	(degrees)
60– 70	65	53	6
70– 80	75	47	14
80– 90	85	43	21
90–100	95	39	28
100–110	105	36	34½
110–120	115	32	41½
120–130	125	27	49
130–140	135	22	56½
140–150	145	16	64½
150–160	155	9	73

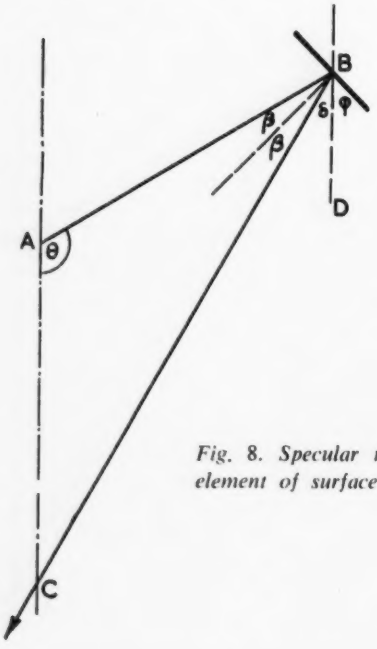

Fig. 8. Specular reflection at an element of surface

vertical; the value of ϕ is most conveniently found from the expression $\phi = \frac{\theta - \delta}{2}$. The justification for this expression will be found in the Appendix. It should be borne in mind that if reflector arrangements (c) or (d) are adopted δ will have a negative value.

Plotting the Reflector Contour

Once the "reflecting scheme" is known, the problem of drawing the reflector contour becomes relatively trivial, and may be accomplished in a number of different ways; only one of these methods will now be described.

Draw lines radiating at 10-deg. intervals from the light-centre, as shown in Fig. 6. Commence marking the reflector contour from the point T, closest to the bulb of the lamp. With the aid of the adjustable set-square, draw the straight line TU between the 160-deg. and the 150-deg. radial lines, at the angle of inclination shown in the fourth column of Table I. Other elements of the reflector may be constructed similarly, giving finally the discontinuous line shown in Fig. 6. The final contour is obtained by drawing a smooth curve tangential to all the elements. See Fig. 7.

Specular Trough Reflectors

A similar procedure may be used for designing a specular trough reflector to provide a given intensity distribution in the plane at right angles to the axis of the trough; in this case the ideal source would not be a point but a straight line, and the zonal lumens should be represented by lines proportional to I_θ, instead of $I_\theta \sin \theta$.

Applications

This method of design has been successfully employed for reflectors for clear tungsten lamps. It suffers from the disadvantage common to all flux methods in that it ignores the fact that the source is not of negligible size. It has, however, been found to be the most rapid method available, since it avoids the laborious arithmetical computations associated with the classical techniques.

Acknowledgments

The author would like to thank Mr. R. A. Hounslow for his advice and encouragement, and the directors of Falk, Stadelmann and Co., Ltd., for permission to publish this work.

Appendix

DERIVATION OF THE EXPRESSION $\phi = \frac{\theta - \delta}{2}$.

In Fig. 8, A represents the light-centre of the source, and B is an element of the reflector surface. The angles ϕ, θ and δ have the same meanings as in Table I. The angle β is the angle which the incident ray and the reflected ray make with the normal to the reflector element. AC is the axis of symmetry of the reflector (assumed vertical), and BD is parallel to AC.

$$\angle ACB = \angle CBD = \delta \quad \text{(alternate angles)}$$

In the triangle ABC:

$$\angle ABC + \angle BCA + \angle CAB = 180 \text{ deg.}$$
$$2\beta + \delta + \theta = 180 \text{ deg.}$$

But:

$$\beta + \delta + \phi = 90 \text{ deg.}$$

Therefore:

$$2\beta + \delta + \theta = 2(\beta + \delta + \phi).$$
$$\phi = \frac{\theta - \delta}{2}.$$

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The Physical Society Exhibition

A brief report on the exhibits at the thirty-ninth exhibition of the Physical Society held in London from April 25-28.

The Exhibition of Scientific Instruments and Apparatus, held annually by the Physical Society, was moved this year from South Kensington to Westminster. As pointed out in the Foreword to the Handbook, considerations of space made it impossible to continue any longer at the traditional venue, the Royal College of Science, and for the first time in the long history of the Exhibition (this one was the 39th) other accommodation had to be found. This year's Exhibition was staged at the Royal Horticultural Society's New Hall, close to Vincent Square, and although this offered the advantage that all the exhibits could be displayed on one floor and not divided among a number of rooms, there seemed to be little if any gain as far as spacing the exhibits was concerned. The aisles between stands were as congested as ever and travelling from one stand to another situated at some distance from it required both time and patience.

The exhibits of direct lighting interest were again comparatively few and there was no series of displays staged by the Colour Group, like that which provided such an attraction last year.

Photometers

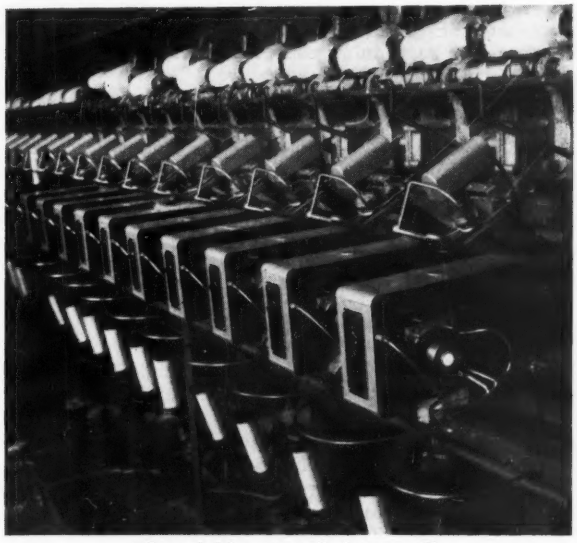
Megatron Limited showed a number of illumination photometers including, in addition to the cosine-corrected instruments for normal values of illumination, shown last year, a new street lighting model with a series of ranges going down to quite low values of illumination. This increased sensitivity is obtained by using a portable mirror galvanometer with a well-balanced movement, a stable zero point and quick action. The cell is provided with a viewfinder and spirit levels to facilitate correct adjustment when in use. The cell holder allows the cell to be tilted and locked at any angle with the horizontal and the angle can be read from a clearly marked scale.

The only other instrument that could properly be described as a photometer was the Siemens spectral band photometer, modified so as to enable measurements to be made in selected bands 10 mμ wide from 330 to 400 mμ in the ultra-violet and from 400 to 440 mμ in the visible. The wave-bands are selected by means of a disc with slits which is rotatable so that any desired slit can be brought into the spectrum plane, thus isolating the desired part of the radiation spectrum and allowing it to fall on a selenium photocell.

Siemens Electric Lamps and Supplies Ltd. also showed a number of other interesting exhibits, among them one which, although primarily concerned with acoustics, was of no little interest to the lighting engineer. This was an instrument used to measure the noise produced by choke ballasts in a fluorescent lamp circuit. It was demonstrated with a number of types of chokes of different designs. Then there was a unit for initiating an electric arc discharge in metal vapours or gases at a very high pressure, by the production of a voltage of the order of 30 to 40 kv in series with the normal mains supply, whether this was a.c. or d.c. There were also two exhibits concerned with radio interference by lamps. One was of equipment used to assess the noise level of a discharge through argon and mercury vapour and it was shown that this noise level increased as the electron emission from the cathodes diminished. The other was a demonstration that certain types of tungsten filament lamps could cause high frequency oscillations between 30 and 100 Mc/s which could interfere with television reception. Normal general service lamps, it was shown, could not produce interference of this kind.

Densitometers

Perhaps densitometers may be classed as photometers. At any rate, instruments of this kind were shown by several exhibitors, notably Joyce, Loebl and Co. Ltd., Evans Electroselenium Ltd. and Baldwin Instrument Co. Ltd. An ingenious recording microphotometer was exhibited by Mr. J. Bor of the Physics Dept., West Ham College of Technology. The basis of this instrument was a Hilger non-recording microphotometer, the selenium cell being replaced with a Schwarz cadmium selenide photo-conducting cell, while the high sensitivity galvanometer of 2.5 sec. period was replaced with a relatively low sensitivity instrument of 0.2 sec. period, so that faithful reproduction could be combined with a high speed of travel of the plate being measured.



Photoslubbers installed in a mill.

Barr and Stroud again showed some interference filters, but in addition they had an exhibit of recent developments in the production of anti-reflection films on glass surfaces.

Photocell Control of Yarn

An interesting application of photo-electric cells was shown by Dawe Instruments Ltd. This was an instrument, designed in collaboration with the Linen Industry Research Association, for controlling the thickness of linen yarn and was called the " Linra Photoslubber." (A " slub " is a length

of yarn of excess thickness and if this is woven into high quality material the commercial value is reduced.) The equipment is intended to locate slubs when the yarn is wound from the spinning bobbins on to the weaving cones. A parallel beam of light from a projector lamp and lens assembly passes through two apertures to two photocells which are mounted side by side and form a balanced system in a differential amplifier. A standard yarn, or a wire of equal light transmission, is fitted across one aperture, while the test yarn passes through the other aperture at the normal speed of several hundred yards per minute. If the test yarn exceeds a predetermined thickness the amplifier output operates a thyratron which has an electromagnetic cutter in the anode circuit and an indicator lamp. The yarn is cut before the slub reaches the cutter so that the slub can be removed by the operator. A number of photoslubbers installed in a mill are shown in the illustration.

Lamp Research

The exhibits shown by the Research Laboratory of the British Thomson-Houston Company included several of lighting interest. First there was the new 4-watt ultra-violet lamp developed for use as a source of long-wave u.v. radiation. This was similar to an ordinary fluorescent lamp except that the special phosphor used converted the 253.7 μ mercury radiation from the discharge into the long-wave u.v. instead of into visible light. The tube was of Wood's glass so that any visible light and all short-wave u.v. was filtered out.

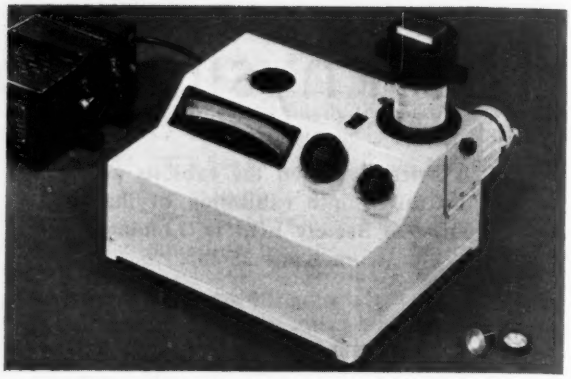
Then there was the high efficiency electro-luminescent panel mentioned by Mr. Ruff during his remarks on the paper by Bowtell and Bate read at the meeting of the Illuminating Engineering Society in April. The efficiency was stated to be 10 lm/w when the panel was operating on a 240-volt 50-cycle supply.

Finally, for the special benefit of the street lighting engineer, there was a simple and inexpensive fluorescent lamp circuit tester used to check whether the instant start circuit in a twin 40-watt 2-ft. fluorescent fitting was operating correctly. The device consists of a pair of dummy tubes which can be inserted in place of the fluorescent lamps. Each dummy contains three small filament lamps and failure of one or more of these lamps to light when the circuit is energised indicates the nature of the fault.

Colorimetry

The Research Laboratories of the General Electric Company showed a photo-electric differential colorimeter applied, in particular, to the measurement of the chromaticity of fluorescent lamps. The instrument uses a selenium photocell and three Dufay-Chromex filters designed to give, in conjunction with the cell, overall spectral sensitivities approximating respectively to the $\bar{x}$, $\bar{y}$, $\bar{z}$ distribution coefficients of the C.I.E. system. The filters are brought in turn in front of the photocell and the photo-electric current is measured by means of the well-known Campbell-Freeth compensating circuit, the balancing e.m.f's so determined being then approximately proportional to the chromaticity co-ordinates. In order to obtain direct readings of chromaticity, the three co-ordinates of which sum to unity, the circuit is arranged so that the sum of these three e.m.f's produces a meter reading which can be adjusted to 1.0. The individual e.m.f's are then measured with the same meter and these readings, after substitutional calibration, are numerically equal to the chromaticity co-ordinates x, y, z of the source.

As it is not practicable to obtain filters which, in combination with the photocell, will produce overall responses exactly identical with the $\bar{x}$, $\bar{y}$, $\bar{z}$ co-efficients, in order to obtain accurate results the instrument must be calibrated by reference to a light source of similar spectral distribution to the test source. Hence, presumably, the use of the word "differential" in the name.



Hilger photo-electric tristimulus colorimeter.

Another exhibit of a colorimeter was that of Hilger and Watts Ltd., who showed their photo-electric tristimulus colorimeter (see illustration). This instrument is used for determining the C.I.E. chromaticity co-ordinates and the reflection or transmission factors of opaque or transparent samples, using any one of the three standard illuminants A, B or C. By means of special accessories it can also be used for liquids and for powders without the intervention of a cover glass. The optical unit has an extensible cable connection and can be removed from the instrument body and applied, for example, to a wall or a large sheet of material.

Recent Developments in Luminescence

As on previous occasions, three discourses (or "demonstration lectures") were given during the course of the Exhibition, which was open from the 25th to the 28th of Aril. The first, by Mr. M. E. Haine, was entiled "The Free Electron as a Tool in Scientific Research," while on the second day Professor J. Z. Young gave an account of experimental work leading to a theory of memory systems in the brain. On the third day the lecture hall was filled to capacity for a most interesting lecture by Dr. G. F. J. Garlick of the Department of Physics in the University of Birmingham in which he described some "Recent Developments in Luminescence and its Applications."

He first dealt with the physical chemistry of phosphors and showed how the subject had developed from the time when the preparation of phosphors was what he described as a "cookery book" process. He dealt in particular with the important case of zinc sulphide containing a small quantity of activator (copper, silver or manganese) and a flux, saying that the green emission band was due to "vacancies" in the crystal caused by a deficiency of zinc. The function of the activator, at any rate in the case of silver, was to facilitate the production of such vacancies. He then went on to describe how comparatively large single crystals of zinc sulphide could be prepared so that their optical and electrical properties could be more conveniently studied. Such crystals were "grown" in a number of different ways, one being to heat purified zinc sulphide (prepared by precipitation) in an atmosphere of hydrogen sulphide under very carefully controlled conditions of temperature and pressure for periods up to 70 hours.

Next Dr. Garlick passed to the subject of electro-luminescence and said that the phosphor used for making the now familiar luminous plaques was a copper activated zinc sulphide prepared by the cookery book method. Each

(*Continued on p.* 255).

Notes on the City and Guilds Examination Papers

By S. S. BEGGS, M.A., F.I.E.S.*

(1) Intermediate Grade

Introduction

Although the extent of knowledge of a subject required for any examination is nominally specified in the published syllabus relating to the course for that examination, the correct interpretation of the syllabus and the standard actually required at any time are only apparent from a study of the questions set in the examination papers over a period of the preceding few years. The standard may change over a long period, and indeed the tendency always is for the standard of an examination to rise gradually as a subject becomes better known and facilities for the teaching of it become more readily available; however, every effort is made by a responsible examining body to avoid random fluctuations in the standard, and to ensure that so far as possible the examination paper provides a fair test of the candidate's knowledge of the subject.

Those students who have presented themselves for the examination will doubtless like to have the questions analysed, and an indication of the sort of answer which might be expected from them (even if it reveals certain deficiencies in the answers which they themselves have given); other students contemplating the examination would also probably find a review of the questions already set helpful. Lighting engineers generally may find such a study of interest, as it will help to indicate the standard that might reasonably be expected of the trained engineer, and the technical status of the profession. It is because the interest may be wider than in the purely scholastic field that the following study of the examination papers set this year has been prepared for publication. The questions are reprinted by permission of the City and Guilds of London Institute, whose co-operation is gratefully acknowledged. However, the interpretation of the questions and the form and content of the answers suggested represent the personal view of the author. Variations from these answers would in many cases be equally acceptable; the important consideration throughout is that the candidate should show a good understanding of the principles and basic ideas involved in the subject matter of the question attempted. The answers given here are necessarily merely in note form and very brief, in order that all the questions in the examination papers may be included; where the answer required is straightforward text-book data, reference will be made to a standard book, such as the "Text-book of Illuminating Engineering (Intermediate Grade)," by J. W. T. Walsh. The answers given by the candidate should, of course, be clear and concise, and should contain all the information requested in the question; they can be as detailed as possible within the time limit of approximately half an hour which can be allowed for each answer.

* Research Laboratories, The General Electric Co., Ltd.

FIRST PAPER

(1). *Describe with illustrative sketches the construction of a primary standard of light at the melting point of platinum. Explain how it is used, state the value of its output in appropriate units, and review its advantages in comparison with earlier primary standards.*

For a description of the usual form of construction and method of use of the present-day primary standard of light, reference should be made to a standard book, such as Walsh's "Textbook." The essential parts of the source are the pure thorium oxide cylinder, the crucible containing the platinum in which the tube is immersed and having a lid with small hole for viewing its interior, and the outer enclosure packed with thoria, except for the channel by which the source is seen. The method, of heating (by high frequency induction furnace) and the optical means for making the measurement on a horizontal photometer bench (by reflecting prism, image forming lens and diaphragm of known size) should be described briefly in the method of use.

By definition, the brightness of the source (viz., the inner surface of the cylinder visible through the small hole in the lid of the crucible, at the temperature corresponding to the melting point of platinum) is 60 candelas per sq. cm.

The great advantage of this primary standard is its fundamental nature, since the source is the closest possible practical approach to a total radiator ("black body"), of which the radiation depends only on its temperature. (The platinum is used only to fix the temperature, and is not the source of light as in the Violle standard). It is not dependent on any particular fuel, as the original oil lamp standards, nor so sensitive to the construction of the lamp and the atmospheric conditions as the flame sources. Neither is it embodied in a few actual lamps, which may be damaged or broken and in any case must depreciate with use, like the electric filament lamp primary standards of the International Candle.

(2). *What is meant by "equality of brightness" and "equality of contrast" in connection with visual photometer heads? Illustrate your answer by reference to typical apparatus, the leading details of which should be sketched.*

The eye cannot judge the ratio of different brightnesses, but under suitable conditions can judge very precisely when two surfaces are equally bright, or when the contrast between a small area and its background of slightly different brightness is the same as that between another similar small area and its background. In the "equality of brightness" photometer head, the two sides of the photometric field are adjusted until they appear to be of equal brightness (luminance). In the "equality of contrast" head, each source under test illuminates the small patch on one side of the field and the background of the other side, the brightness of the patch being a constant few per cent. lower than that of the background illuminated by the same source. In making the balance, the contrast between the patch and its immediate background (illuminated by the other source) is

adjusted to be the same for the two halves of the photometric field.

Probably the most common construction of photometer heads of these two forms are the Lummer-Brodhun patterns, of which full details and suitable sketches are given in the text-books. (Other forms, e.g., the Bunsen head, may be described if the candidate is more familiar with such alternatives, but the Lummer-Brodhun pattern is usual in practice for precise work, and the essential difference between its two forms is only in the photometric "cube.") In describing the Lummer-Brodhun head, the arrangement of diffusing screen, reflecting mirrors *or* prisms, photometric cube, and eyepiece should be briefly shown, as these are the essential components: the two forms of the photometric prism (including the contrast slips where used), the paths of the light rays and the appearance of the field should be described more fully, as their difference is the essence of this question.

(3). *Explain what is meant by polarised light. Name three materials which exhibit the polarising property and give three examples of the practical use of polarised light.*

Light is radiant energy, in the form of a wavetrain of periodically varying electromagnetic field, the directions of the electric and magnetic forces at any point lying in a plane perpendicular to the direction of the ray at that point. In ordinary light, the direction of such forces varies in a random manner in this plane, on the average being as frequently in one direction as another: in polarised light the direction of the force is constrained to vary in a regular manner, and in "plane polarised" light it lies always in the same plane containing the direction of the ray. Although the eye cannot detect polarisation of light, it is of practical importance since some characteristics, such as reflection or transmission by materials, may depend markedly on the polarisation.

Any three polarising materials may be named; examples are: calcite (Iceland spar), tourmaline, "polaroid" by transmission, and water, glass or glazed surfaces and similar non-metallic polished materials by specular reflection.

Again any three practical uses of polarised light may be described. Examples are: in optical or photometric instruments, in which the intensity of the light has to be varied in a known manner; to study strains in transparent materials such as moulded glass, or in mechanical parts of which models can be made in transparent material and suitably loaded; to study the physical nature of materials, e.g., crystalline materials by transmitted light, or surface flaws or composition by changes in reflection characteristics; for revealing instrument dials or a glazed picture with the avoidance of objectionable high lights or glare, by using light polarised at right angles to the plane of incidence. (*Note.* The question asks for the practical use of *polarised light*: uses of polarising *material*, e.g., for the absorption of glaring light, should not be given instead.)

(4). *Give an account of the theory of combustion of town gas, and exemplify your answer by reference to a gas of a representative assumed composition. Explain why gas lighting using incandescent mantles is more efficient than luminous flame lighting.*

Town gas is composed mainly of hydrogen, methane and carbon monoxide, and for a calorific value of 500 B.Th.U. per cu. ft. in approximate proportions respectively of 48, 24 and 16 per cent. of the total mixture (the remaining 12 per cent. being small amounts of other gases, such as nitrogen, oxygen and carbon dioxide). When mixed with air and ignited, these combine with oxygen from the air to form carbon dioxide and water, about $4\frac{1}{4}$ times as much air as gas being required for complete combustion. If less than this proportion of air is mixed with the gas before ignition (primary air), the remainder may be obtained from the air surrounding the flame (secondary air), but the temperature of the flame generally decreases with decreasing proportion of primary air.

In a luminous gas flame the light is obtained from particles of carbon (from hydro-carbons in the gas mixture) raised to incandescence in the flame, and as the temperature is relatively low (about 1,500-2,000 deg. K) the efficiency of light production is low. With an incandescent mantle a hot (almost non-luminous) flame may be used to heat the material of the mantle, so the temperature of the emission is much higher. In addition the mantle can be made of materials (such as the Welsbach ceria-thoria mixture) which are selective radiators, to make the luminous efficiency for a given power dissipation greater than that of almost "black body" radiation from the carbon particles of the luminous flame.

(5). *It is observed that coloured objects do not appear the same when viewed in* (1) *daylight,* (2) *incandescent filament light,* (3) *sodium discharge light, and* (4) *mercury discharge light (non-fluorescent). Give reasons for this and state what you would expect in viewing red, green and blue postage stamps when illuminated in each of these ways.*

The apparent colour of an object depends on both the variation of its reflection factor for light of different wavelengths and the spectral composition of the light incident on it. It will reflect little light of any wave-length for which its reflection factor is low (however much light of this wavelength is contained in the incident light); and it cannot reflect much light of any wave-length of which the incident light is relatively deficient (however high its reflection factor for that wave-length). Reflection from a coloured object therefore tends to accentuate those hues which are *both* relatively strong in the incident light and for which the body has a high reflection factor, whilst suppressing those hues *either* lacking in the incident light *or* for which the reflection factor is low.

The printing inks of the stamps reflect a band of wavelengths centred on the named colours. Daylight contains approximately equal amounts of all wave-lengths, so the three stamps would appear in their "natural" colours, as named. The incandescent filament light is deficient in the shorter wave-lengths and strong in the long wave-lengths; the red stamp will therefore appear a stronger red than by daylight, the green will not appear much different (perhaps a little duller), but the blue stamp will appear dark and the colour hard to determine. Under the almost monochromatic light from the sodium lamp, all the stamps will look of much the same brown colour (the white edging and lettering being yellow), whilst under the mercury discharge light, which has a strong green line and some blue, but no visible radiation of long wave-length, the green stamp will look brightest and of "truest" colour, the blue stamp will look a greenish blue, and the red stamp a dark maroon or chocolate brown.

(6). *Two rays of light from a uniform common source S reach a point of comparison C. The ray A is reflected by mirrors at M_1, M_2 and M_3 as shown in Fig. 1; the ray B passes through a neutral filter F. The distance SC is 5 ft. and the distances $M_1 M_2$ and $M_2 M_3$ are each 6 in.; the mirrors are very small and thin in comparison with these distances. The efficiency of reflection at each mirror surface is 85 per cent. and the filter F is made of a material such that a thickness of 0.05 in. transmits 50 per cent. of the incident light.*

Determine (i) the ratio of the illumination values produced at C by the two rays if F is withdrawn, and (ii) the thickness of F if this ratio is unity when F is included.

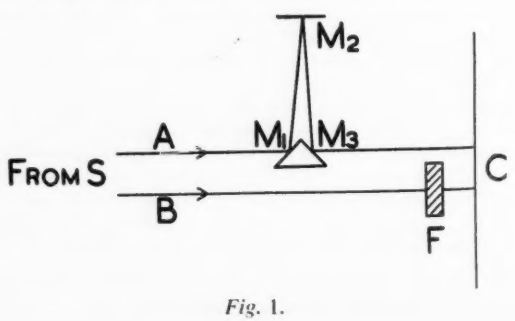


Fig. 1.

(i) Suppose the intensity of the source in the direction of C is I candelas. Since the distance traversed by ray A is 6 ft., but of the light reaching each mirror only 85 per cent. is reflected,

illumination at C by ray A

$$= \frac{I \times (0.85)^3}{6^2} \text{ lm/ft}^2$$

Illumination at C by ray B, without F in place,

$$= \frac{I}{5^2} \text{ lm/ft}^2$$

Hence the ratio of the two illumination values

$$= \frac{I \times (0.85)^3}{6^2} \times \frac{5^2}{I}$$

$$= \frac{(0.85)^3 \times 5^2}{6^2} = \underline{0.426 \text{ to 3 significant figures.}}$$

(ii) To make the illumination values equal when F is in place, the transmission of F must be 0.426. Since the light is reduced by half for every 0.05 in. of thickness of F, if the thickness of F is t inches, its transmission will be $(0.5)^{t/0.05}$

Hence $(0.5)^{t/0.05} = 0.426$,

$$\text{or } \frac{t}{0.05} = \log (0.5) = \log (0.426).$$

$$\text{Thus } t = \frac{0.05 \log 0.426}{\log 0.5} = 0.05 \times 1.174 = \underline{0.058_7 \text{ in.}}$$

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(7). *A photographic exposure meter has been proposed in which the aperture of the iris of an observer's eye may be measured while he is looking at the field which it is desired to photograph.*

From what you know of the structure and behaviour of the eye, state whether or not you would regard this measurement as a satisfactory criterion for the purpose, setting out the arguments leading to your decision.

No, this measurement would not be a satisfactory criterion for the determination of photographic exposure.

Correct photographic exposure is determined by the brightness of the scene to be recorded; the brightness concerned may be that of the brightest part or of the darkest part, or as an approximation the average brightness of the scene, according to the technique adopted by the photographer. The size of the pupil aperture is not closely related to any of these quantities.

The total range in diameter is not more than 4 to 1, so the measurement would have to be very critical to serve for the enormous range of possible brightness of scenes. The main function of the iris is to minimise the effect of sudden changes of brightness presented to the eye; the pupil may decrease or increase temporarily and return to about the same size when the retina has had time to adjust its sensitivity to the brighter or darker scene. The pupil size is near its minimum for most conditions of full daylight, and near its maximum for most conditions of artificial light. The pupil size therefore does not provide a precise and unique measure of the scene brightness. Moreover, the size of the pupil varies considerably between individuals.

The eye has other disadvantages for this purpose, since light passing obliquely through the pupil is much less effective than more direct light, partly because of poorer transmission by the lens and partly because of the structure and response of the retina. Thus the brightness of objects viewed obliquely will not be evaluated in correct proportion to those in the centre of the scene.

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(8). *The mean axial polar curve of intensity distribution from a light source is as follows:*

Angle from axis (degrees)	0	10	20	30	40	50	60	70	80	90
Luminous intensity (candelas)	450	440	400	300	155	100	60	35	15	0

There is no emission for angles greater than 90 deg. Determine by any normal method the total light flux emitted (i) between the angles of 0 and 45 deg., and (ii) between the angles of 0 and 180 deg. Justify the method used.

The light flux emitted in any solid angle is given by the product of the values of the solid angle and the mean intensity throughout that angle.

Since in the given light distribution the intensity is a maximum in the direction of the axis and falls away steadily as the inclination to the axis increases, the flux in 10-deg. zones about the axis will not vary enormously, so the use of zone factors for 10-deg. intervals should be satisfactory; also the mean of the intensities at the limiting angles of each such zone may be taken as the mean value through the zone, sufficiently accurately for most purposes.

Zone A_1—A_2 (degrees) :	0 — 10	10 — 20	20 — 30	30 — 40	40 — 50	50 — 60	60 — 70	70 — 80	80 — 90	90 — 180
Cos A :	1.0 — .985	.985 — .940	.940 — .866	.866 — .766	.766 — .643	.643 — .500	.500 — .342	.342 — .174	.174 — 0	0 — −1.0
Zone Factor/2π :	.015	.045	.074	.100	.123	.143	.158	.168	.174	1.0
Intensity :	450 — 440	440 — 400	400 — 300	300 — 155	155 — 100	100 — 60	60 — 35	35 — 15	15 — 0	0
Mean Intensity :	445	420	350	227	127	80	47	25	7	0
Zonal flux/2π :	6.7	18.9	25.9	22.7	15.6	11.4	7.4	4.2	1.2	0

The Zone Factor Z for a zone extending from angle A_1 to angle A_2 is given by $Z/2\pi = (\cos A_1 - \cos A_2)$, and Zonal Flux f by $f = 2\pi \frac{(I_1 + I_2)}{2} (\cos A_1 - \cos A_2)$ lumens.

We may therefore proceed as follows:—

The fluz in the zone 40—45 deg. may be taken to be approximately half the flux in the zone 40—50 deg., viz $2\pi(7.8)$ lumens.

Hence flux in zone 0—45 deg.

$$= 2\pi (6.7 + 18.9 + 25.9 + 22.7 + 7.8)$$
$$= 2\pi (82)$$
$$= \underline{515 \text{ lumens, approximately;}}$$

and flux in zone 0—180 deg.

$$= 2\pi (82 + 7.8 + 11.4 + 7.4 + 4.2 + 1.2)$$
$$= 2\pi (114)$$
$$= \underline{720 \text{ lumens, approximately.}}$$

(*Note*: A solution using appropriate Russell Angles would be equally suitable.)

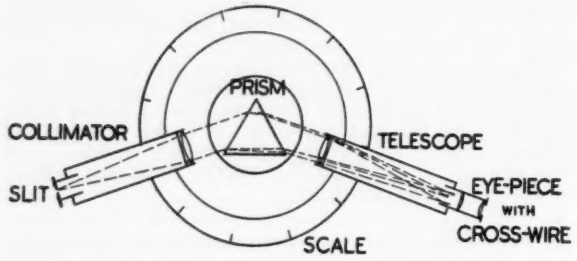


Fig. 2. Essential parts of a prism spectrometer

(9). *Describe the construction of a prism spectrometer and explain how it may be used to map the visible spectrum of a light source. Give an idea of the results to be expected in the case of any particular light source of your choice.*

The essential parts of a prism spectrometer are shown in Fig. 2. They are a small aperture (usually a slit), a collimator, a refracting prism, a telescope with crosswire or graticule in the eyepiece, and an angular scale to indicate the position of the telescope relative to the slit and prism. The slit is at the focus of the collimating lens, so that light from a source placed close to the slit is incident on the prism in a substantially parallel beam. Light of different wave-length is deviated by different amounts, and therefore reaches the telescope objective lens in slightly different directions, but the rays of light of any one wave-length are still parallel. The telescope therefore forms a row of coloured images of the slit in the focal plane of the objective lens. These can be viewed in turn in the eyepiece of the telescope, by moving it around the prism until any selected image coincides with the crosswire, and the position of the telescope on the scale for each is noted. By first using a source of known spectral light distribution, the position of the telescope for the known wave-lengths of light can be determined, and the telescope position scale thereby calibrated in terms of the wave-length of the light forming the slit image viewed.

Of the radiation from the sodium vapour lamp which falls within the visible spectrum almost all is at the doublet 5890 Å and 5896 Å. (There is a little radiation in another doublet at 5683 Å and 5688 Å.) The visible spectrum of this source therefore appears as a strong single yellow line, except in a very good spectrometer, which can resolve the two very close lines.

(*Note*: The sodium vapour lamp spectrum is the simplest to describe, but the spectrum of an incandescent source or another discharge lamp would be equally acceptable for this answer; however, only *one* should be given.)

SECOND PAPER

(1). *What are the two laws governing the refraction of a ray of light through a transparent medium? Show how total internal reflection may occur, defining the Critical Angle and evaluating it for material of refractive index* 1.52 *in air (refractive index* 1.0).

The two laws are: (1) The incident ray, the refracted ray and the normal to the surface at the point of incidence lie in one plane, and (2) The ratio of the sines of the angles which the incident and refracted rays make with the normal to the surface is equal to the ratio of the reciprocals of the refractive indices of the media containing the incident and refracted rays.

If light passes from a medium of higher refractive index μ_A to one of lower refractive index μ_B, the sine of the angle which the emergent ray makes with the normal is greater than the sine of the angle between the normal and the incident ray. As the latter angle increases from zero, the former will increase more rapidly, and will approach 90 deg. as the former approaches the angle whose sine is equal to μ_B/μ_A. For greater angles of incidence, the angle of refraction would have to have a sine of value greater than unity, which is impossible. Thus for angles of incidence greater than that whose sine is μ_B/μ_A no light is refracted, but all the light is reflected. This angle is know as the Critical Angle for the two media with refractive indices μ_A and μ_B

If $\mu_A = 1.52$ and $\mu_B = 1.0$, the Critical Angle is the angle whose sine is 1/1.52, i.e., 0.658. For this material in air, therefore, the Critical Angle is $\sin^{-1} 0.658$, viz. 41.1_5 deg.

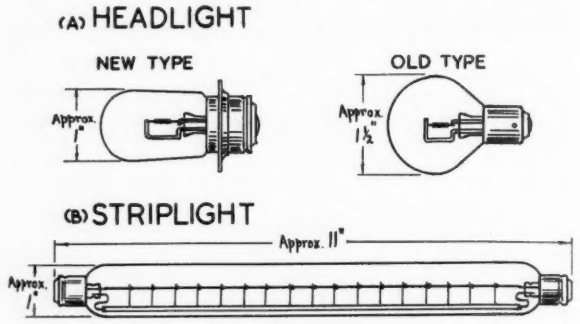


Fig. 3. Headlight and striplight lamps

(2). *Give a description with diagrams of: either (a) a 12-volt 36-watt incandescent filament lamp for use in a motor car headlight, or (b) a 240-volt 60-watt "striplight" lamp (i.e., a lamp with a long filament).*

Both these lamps must surely be well known, but examples are illustrated in Fig. 3. (*Note*: Only *one* should be described in answer to this question.)

(a) The main features to be noted in the car headlight lamp are: (1) the short thick linear axial filament, to give a narrow beam not too critically dependent on exact location in the reflector, (2) the bulb of minimum size, to reduce obstruction of reflected light; also in the new type to permit the lamp to be inserted from the back of the reflector, and in the larger old type with tapered shoulders to allow the lamp to be used in a parabolic reflector of short focal length, (3) the stout filament support wires, for rigidity and robustness, (4) the small bayonet cap in the old type and prefocus cap in the new type, for adequate location of the lamp in the reflector with no danger of shaking loose with vibration, (5) gas filling, for maximum brightness of source.

(b) The main features of the striplight lamp are: (1) the long straight filament, to give very small source dimension in planes normal to the axis of the lamp for close control of light distribution, or to suit lines of installation, (2) bulb of small diameter for use in small size reflector, or for ease of concealment of the lamp in small space, (3) many light springy filament support wires, to locate the filament reasonably accurately, and minimise the effect of mechanical shock on the delicate filament, whilst avoiding excessive cooling of the filament by conduction away of heat, (4) the "pinch" and cylindrical cap at each end of the lamp bulb, for good location and safe support of this long bulb, with convenient contacts with the filament, (5) vacuum around filament to avoid cooling by gas of large exposed surface area.

(3). *A perfectly diffusing disc emits F lumens from one side. Prove that the maximum intensity from the disc is* F/π *candelas.*

The intensity of a source in any direction is given by the product of the (mean) brightness of the source in that direction and the area of the source projected on a plane normal to that direction. The projected area of the disc is proportional to the cosine of the angle between the direction concerned and the normal to the plane of the disc, whilst its brightness is constant for all directions. If the true area of the disc is A sq. ft. and its brightness B candelas/sq. ft. the intensity $I\theta$ in any direction making an angle θ with the normal is therefore given by $I_\theta = A.B.\cos\theta$ candelas. The light distribution is symmetrical. The flux can therefore be evaluated by direct integration,

by Zone Factors, Russell Angles or any other convenient standard method.

By direct integration, since the elemental zone at angle θ is $2\pi . \sin\theta . d\theta$

$$\text{flux emitted by disc } F = \int_0^{\pi/2} (A.B. \cos\theta)\, 2\pi . \sin\theta . d\theta$$

$$= 2\pi AB \int_0^1 x . dx \quad (\text{if } x = \sin\theta) \quad = \pi AB[x^2]_0^1 = \pi AB \text{ lumens}$$

The maximum intensity of the disc clearly is in the direction $\theta = 0$, and from above $I_o = A.B. = F/\pi$ candelas.

(4). *Define the term "daylight factor." How may this factor be related to illumination and how may an estimate be made of the time during which a point in an interior receives at least a specified illumination? Illustrate your answer with graphs where appropriate.*

"Daylight factor" is the ratio (usually expressed as a percentage) of the illumination on a horizontal surface at a point inside a building to the illumination on a horizontal surface exposed to the whole hemisphere of sky outside the building at the same time; direct sunlight is excluded from both measurements and the brightness of the sky should be as uniform as practicable.

(*Note.* The wording of the next part of this question is not explicit but a reasonable interpretation might be as follows.)

The illumination at any point in the building bears an approximately constant ratio to the illumination out of doors (excluding direct sunlight), which by definition is the Daylight Factor. If any specified minimum value of illumination is required at the point, the value which the external illumination must exceed to ensure this illumination can be calculated, viz., the quotient of the specified illumination value and the Daylight Factor for the point in question.

Records have been kept over long periods of the variation of the illumination from the whole sky, and data are available showing the variation throughout the day of the mean value to be expected for any month of the year.

(Typical curves are shown in the text-book by Walsh and should be reproduced approximately in answer to this question.)

The estimated time during which the illumination at the given point in the interior with Daylight Factor D receives at least a specified illumination E lm/ft² is the sum of those hours for which the external illumination as shown on graphs such as these exceeds the value E/D lm/ft².

(5). *Give a short account of the following visual phenomena with an example of each: persistence of vision; disability glare; stereoscopic vision; dark adaptation; simultaneous contrast.*

(1) Persistence of vision is the continuation of the sensation of vision after the stimulus of light received on the retina has ceased. The length of interval between stimuli which may occur whilst retaining the sensation of continuity depends on several factors, e.g., brightness of the field of view, colour of the light and the part of the retina receiving the light. Persistence of vision is made use of in the presentation of "moving pictures," in which the short blackout interval is used to change the picture.

(2) Disability glare is the deleterious effect of a region of high brightness in the field of view, reducing the ability of the eye to see the view presented to it; the reduction in visibility may be great or small, and may or may not be accompanied by discomfort. The result of meeting an approaching car with headlights on an unlighted country road at night is an extreme example of disability glare.

(3) Stereoscopic vision is the appreciation by sight of the relative position of objects in three-dimensional space; the objects appear to "stand out." It demands the use of both eyes, and is a function of convergence rather than accommodation; the effect may be enhanced artificially by arranging that the views presented to the two eyes are from widely separated view points. It is made use of mainly in locating close work, such as threading a needle.

(4) Dark adaptation is the readjustment of sensitivity of the retina when the brightness of the scene presented to the eye is suddenly greatly decreased. Vision will never be as good at the low level as at the higher; immediately after the change it is negligible, but will improve rapidly at first and then more slowly, the rate and total time depending on both the initial and final levels of brightness. An example is the increase in ease of seeing surroundings after being in a cinema for some time.

(5) Simultaneous contrast is the enhancement of apparent difference in brightness or colour of two surfaces when viewed in close proximity (especially near adjacent edges); the reaction in the part of the retina stimulated by each area affects the sensitivity of response of the adjacent part. Dark areas appear darker and light areas lighter; the hues of an object and its background will each tend to appear to contain more of the complementary hue of the other. An example is the use of a black surround to a cinema screen, to increase the apparent level and uniformity of brightness of the picture screen.

(6). *A light source $\frac{1}{2}$ in. long and $\frac{1}{8}$ in. wide has a luminance of 1,000 stilb. Calculate its luminance in candelas per sq. in. Parallel to this source at a distance of 7 ft. is a surface having a reflection factor of 0.8. Calculate its luminance when irradiated by the source, expressing the answer in lamberts and foot-lamberts. (Take 1 in. as equal to 2.54 cm.)*

(1) Since 1 stilb equals 1 candela per sq. cm., and 1 sq. in. equals $(2.54)^2$ sq. cm.
luminance of source $= (2.54)^2 . 1{,}000 = 6{,}450$ cd. per sq. in.

(2) Area of source $= (\frac{1}{2} \times \frac{1}{8}) = \frac{1}{16}$ sq. in.

Therefore, intensity of source $= \dfrac{6{,}450}{16}$ cd., and illumination of parallel surface at 7 ft. distance $= \dfrac{6{,}450}{16 \times (7)^2}$ lm/ft².

Note: It is not stated that the surface is a uniform diffuser, nor whether the reflection factor is total, direct or diffuse. Its luminance will depend on the mode of reflection, e.g. being 0.8 times that of the source in the direction of regular reflection and zero elsewhere for regular reflection. However, it is probable that the figure of 0.8 is intended to be the luminance factor in the direction concerned, i.e., the ratio of the luminance of the surface to that which it would have if it were a perfect diffuser, as this is the useful practical factor which relates the luminance of a surface to the illumination which it receives.

A perfect diffuser receiving this illumination reflects $\dfrac{6{,}450}{16 \times (7)^2}$ lm/ft² or $\dfrac{6{,}450}{16 \times (7)^2 \times (12 \times 2.54)^2}$ lm./cm²., and its luminance is therefore $\dfrac{6{,}450}{16 \times 49}$ ft.-lamberts or $\dfrac{1{,}000}{16 \times 49 \times 144}$ lamberts. Interpreting the reflection factor of 0.8 as described above, luminance of given surface is $\left(\dfrac{8 \times 645}{16 \times 49}\right)$ ft.-lamberts, or $\left(\dfrac{800}{16 \times 49 \times 144}\right)$ lambert, i.e.,

6.58 ft.-lamberts or .0071 lambert.

(7). *A television set assembly shop is 50 ft. wide by 150 ft. long by 30 ft. high. One long side is occupied by windows. Plan a lighting scheme for this shop making some recommendations for the decorations.*

In the assembly of television sets, small parts have to be handled and secured in position in an assembly of moderate complexity, and some of the work involves working inside the cabinet. The level of illumination of general lighting should therefore be fairly high on both horizontal and vertical surfaces; additional local lighting may be required in certain positions. Full advantage of the height of the room should be taken, to avoid direct glare; a mounting height of at least 20 ft. is desirable. Lamps of low

brightness are advantageous, since some of the materials (in particular cabinets) have an appreciable degree of polish tending to give local bright reflections. It is important that the light should give fairly good colour rendering, since the rating of many of the electrical components is identified by a code of coloured markings.

The use of light shades of paint for the decoration of the room increases both the efficiency of utilisation of the light and the amenity of the workroom. The bench area also should be treated in a light shade, preferably contrasting pleasantly with the walls and ceiling. This helps to reduce excessive contrasts and to reveal small tools and parts placed on the bench as well as encouraging cleanliness. The large window area should be provided with light-coloured blinds, to avoid the excessive contrast of the dark windows at night, in addition to improving materially the uniformity and efficiency of utilisation of the artificial light; a slightly darker shade of the same colour as the walls would be pleasing.

Tubular fluorescent lamps (of either hot or cold cathode type) in diffusing reflectors would be suitable lamps and fittings for this installation. With a proper decoration scheme, the coefficient of utilisation should exceed 50 per cent. and depreciation should not be rapid as the work is clean. Continuous rows of twin-tube units parallel to either wall and 25 ft. apart should provide satisfactory average service illumination of 20 lm/ft². (For twin 80-watt daylight lamps on 6 ft. centres in line, average service illumination would be about $\left(\frac{2 \times 3{,}600 \times 0.5 \times 0.85}{6 \times 25}\right)$ i.e., 20.4 lm/ft².) This arrangement provides adequate diffusion of the light, and is economical in both installation and running costs.

(8). *Either* (1) *Describe with the aid of diagrams an* 80*-watt tubular fluorescent low pressure discharge lamp for operation on a* 240*-volt* 50*-c/s a.c. supply in a circuit designed for rapid starting, or* (2) *Describe briefly the construction and method of manufacture of a low pressure inverted gas mantle, indicating the means by which high efficiency of operation is achieved.*

(1) The construction of an 80-watt tubular fluorescent lamp must surely be familiar, and has been described in many publications. It will therefore not be repeated in detail here; the main features to be noted are (a) the enclosing tube, (b) the internal coating of fluorescent powder, (c) the coiled wire electrode coated with alkaline earth oxides for high emission of electrons when hot, (d) the mercury vapour and inert gas filling at low pressure, (e) the bayonet-type lamp cap with two contacts at each end for initial heating of the electrodes and connection to the main energy supply, and (f) the means for ensuring rapid starting of the lamp. The last-named item could take any one of several forms, but in Britain is usually either a metallic strip or wire along the full length of the lamp (with means in the fitting for earthing it), or a coating of water-repellent silicone on the outside of the tube (as moisture provides a leakage path, which reduces the voltage gradient available for striking the discharge). (*Note.* The question does not demand a description of the auxiliary gear and circuit. A diagram of the lamp is indicated.)

(2) The construction of the low pressure gas mantle is similarly well known; the main parts are (a) the mantle, consisting of a web of ceria and thoria in the form of a bag, in shape approximately a squat cylinder (height equal to diameter) with a hemispherical lower end, and (b) a ceramic ring with three equally spaced lugs by which the mantle is suspended from the burner

The method of manufacture is given in the text-books; mention should be made specifically of (a) the preparation of the basic fabric from artificial silk or ramie fibre, (b) which is burned away after impregnation with strictly controlled amounts of thorium and cerium nitrates, of which the ash subsequently forms the light source, (c) this being strengthened for handling by dipping in a solution of collodion (burned off before use).

The high efficiency of operation is achieved by using the ceria-thoria mixture in the proportion of approximately 1 per cent. ceria which gives maximum emission of light for a given energy input, and a properly aerated burner of Bunsen type, giving a hot flame which just fits the mantle.

(9). *An indirect lighting fitting consists of a hemisphere internally painted with a good diffusing paint having a reflection factor of* 80 *per cent. The aperture is horizontal and faces upwards. A small source emitting* 100 *candelas uniformly in all directions is placed in the centre of the mouth level with the aperture. Ignoring inter-reflection within the bowl, draw a polar curve of light distribution for the bare lamp and for the light reflected from the bowl, and hence estimate the light distribution of the fittings.*

The light distributions of both bare lamp and reflector are symmetrical about a vertical axis, and may be shown by the curve for a vertical plane. The polar curve of light distribution of the bare lamp will be a circle, centred on the origin, and with radius representing 100 candelas to the scale of the diagram (curve A of Fig. 4). The directly emitted

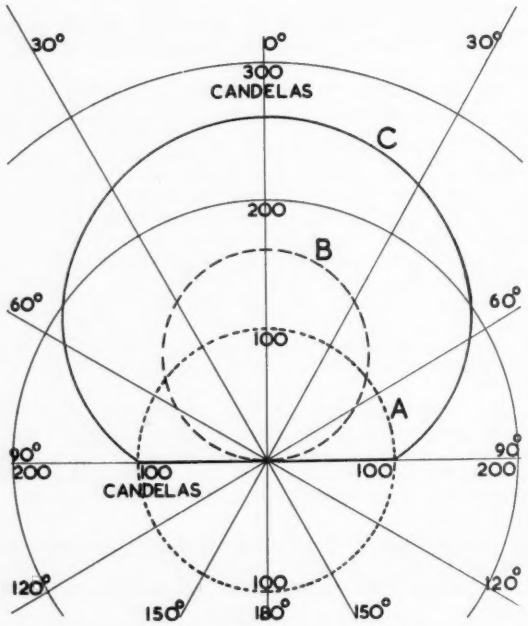


Fig. 4. Polar curves of light distribution

light from a fitting will be the semi-circle forming the upper part of this curve.

The light flux falling on the hemisphere $= (2\pi \times 100)$ lumens and the light flux reflected $= (0.8 \times 2\pi \times 100)$ lumens. Ignoring inter-reflections, the surface of the hemisphere is of uniform luminance, and hence radiates like a uniformly diffusing disc, coinciding with the circular mouth of the reflector. The polar curve of light distribution for such a disc would be a circle, tangential at the origin to the line representing the horizontal plane of the disc, and lying above it. The maximum intensity, vertically upwards, would be $\left(\frac{0.8 \times 2\pi \times 100}{\pi}\right)$ candelas, i.e., 160 candelas. The polar curve of distribution of reflected light is therefore approximately as shown by curve B of Fig. 4, and that of the complete indirect lighting fitting by the combination of curves A and B, as shown in curve C of Fig. 4.

NEW PRODUCTS

"Luve-tile" Illuminated Ceilings

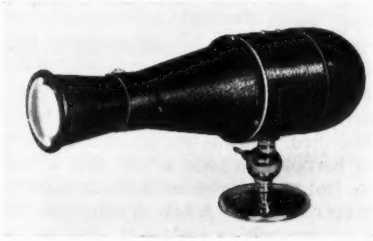
Harris and Sheldon (Electrical) Ltd. have secured the sole rights relating to "Luve-tile" in this country. "Luve-tile" is moulded in polystyrene, in a standard unit or tile measuring 12 in. x 12 in. x 2½ in. deep divided into approximately 2¼ in. square cells. This has been found to be the optimum size considering appearance, light cut-off and diffusion. These and two other components, joiner clips and hanger assemblies, are all that are required, in appropriate quantities, to install a complete illuminated ceiling.

The standard tiles are clipped together with the joiner clips which snap into specially moulded recesses near the corners of each tile. Nine square feet is the maximum recommended for these sub-assemblies for reasons of convenience of handling. With the predetermined dimensions of these sub-assemblies in mind the positions of the hangers are marked on the ceilings with one hanger where the corners of each sub-assembly will meet.

Hanger assemblies consist of a small bracket screwed to the ceiling at the marked points. To this is attached an ⅛ in. rod. The 30-in. rods supplied are cut to size on the site, and grub screw adjustment subsequently ensures final levelling. Attached to the end of the rod are hanger clips each with four spring steel prongs; each prong snaps into the moulded recess on the corner tile of four adjacent sub-assemblies. Two hangers will support one edge "door" fashion, allowing it to hinge down through 90 deg.; this is the action adopted in placing the "doors" in position when building up a complete ceiling.

Spotlight Fitting

The Courtney, Pope (Electrical), Ltd., "Atomette" side-mounting projector spotlight unit has focusing adjustment utilising "Stelmar" optical system with a 24-volt 48-watt S.B.C. double-pole lamp. A 24-volt output mains transformer is utilised in conjunction with the fitting. The standard unit is designed to have a throw of 10 ft. and illuminate an area of 9 sq. ft. The area illuminated can be made to any desired shape and a suitable silhouette slide

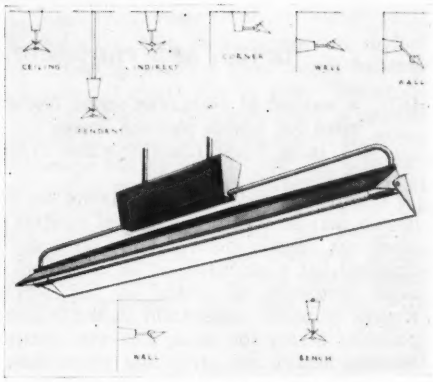


inserted in the optical system in order that sharp definition to the perimeter of the subject illuminated is obtained. To adjust the throw and area to be illuminated, lenses of varying focal lengths can be fitted. Can be used for display work, lighting of pictures, posters, etc.

13-amp. Socket Outlets

The latest range of eleven new flush and surface-mounting 13-amp. socket outlets, introduced by J. A. Crabtree and Co., Ltd., will no doubt be welcomed by engineers, architects, contractors and users. They are available in switched or unswitched patterns and their appearance reflects the high standard of quality that has been achieved. Both shockproof (brown or cream finish) and metal plate units (in a variety of finishes) are listed. The surface-mounting units are particularly pleasing in appearance.

LUMINAIRES . . . . . No. 9



Metalform Ltd.

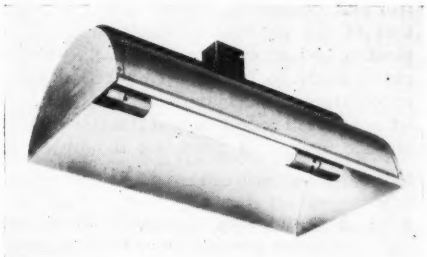
Price :—£10

Primarily for industrial and commercial use, this fluorescent luminaire (5 ft. 80-watt) is adjustable to give a choice of mounting positions; it incorporates movable reflectors to provide various cut-offs and gives a high proportion of light above the horizontal. The mounting-plate can be fixed direct to walls or ceiling, to a standard conduit box, or clamped direct to conduit; for pendant mounting the plate can be attached to two tubular down rods or suspension chains.

Holophane Ltd.

Price :—£4 2s.

A compact circular bulkhead fitting for recessing into ceilings and walls. It is an alternative to the surface mounting type and is suitable for any situation where a bulkhead unit is required. Will withstand rough usage and variable atmospheric conditions; a specially designed rubber seal gives effective proof against dust and moisture. For use with 100-150-watt B.C. Pearl lamps, it incorporates a prismatic cover glass which provides a wide lateral distribution. A pressurised version is also available.



B.T.H. Co., Ltd.

Price :— £11 10s.

A special reflector fitting for use with the recently introduced 1-kw. horizontally operated mercury arc lamp at mounting heights of from 25 to 45 ft. The fitting has a cast-aluminium alloy main channel finished in green, mounting an anodised aluminium trough reflector. A removable side panel in the main channel gives access to a porcelain connector block, ready wired to the two special spring-loaded porcelain lampholders. The design of the lampholders, aided by a ring on one lamp cap, ensures that the lamp is inserted the right way round and in complete safety. The closed end reflector has a matt finish and gives a nearly symmetrical light distribution; it is easily removable for cleaning. No magnetic arc control is needed.

Lighting Abstracts

OPTICS AND PHOTOMETRY

535.8

167. A method of evaluating seeing distances on a straight road for vehicle meeting beams.

V. J. JEHU, *Trans. Illum. Eng. Soc.* (*London*), **20** (*No.* 2, 1955).

Describes a method of calculating the distances at which objects may be seen in the light of a driver's own headlamps when one vehicle meets another on a straight road. Data obtained for a standard set of conditions are extended to other conditions by means of the Stiles-Holladay Law. Results from the application of the method to four object positions across the road, and with British and American meeting beams, are given and show close agreement with practice. W. R.

168. Reflectance of magnesium oxide. 535.39

P. A. TELLEX AND J. R. WALDRON, *J. Opt,. Soc. Am.*, **45,** 19-22 (*Jan.*, 1955).

The photometric sphere method was used to investigate the spectral reflection properties of smoked magnesium oxide. A sphere with a glass wall was used so that the thickness of the oxide deposit could be controlled by observing the optical transmission. Various coating techniques were investigated, and a method of electrostatic deposition finally adopted. Curves are given for the spectral reflection factor of magnesium oxide in various thicknesses up to 8 mm. E. J. G.

169. Luminance of equally bright colours. 612.843.36

A. CHAPANIS AND R. M. HALSEY, *J. Opt. Soc. Am.*, **45,** 1-6 (*Jan.*, 1955).

A description is given of a series of measurements in heterochromatic photometry. It is found that a direct comparison of the brightnesses of two different colours often gives results appreciably different from those predicted by the C.I.E. system. With the exception of yellows, the saturated colours appear appreciably brighter than unsaturated colours of the same C.I.E. luminance. E. J G.

170. Materials for light control. 535.3

Illum. Engng., **50,** 98-99 (*Feb.*, 1955).

Report of an American I.E.S. Committee on Light Control and Equipment Design giving a comprehensive tabulation of the physical characteristics of aluminium, glass, plastics and applied coatings (e.g., porcelain enamel, silver plate) likely to be required when designing luminaires incorporating these materials. Examples of these characteristics are light reflection and transmission, index of refraction, surface finish and resistance to impact, heat, abrasion and corrosion. P. P.

535.8

171. A comparison of some common headlight beams for vehicles meeting on a straight road.

V. J. JEHU, *Trans. Illum. Engng. Soc.* (*London*), **20** (No. 2, 1955).

The method of evaluating seeing distances described in the previous paper is applied to a comparison of the British and American headlighting systems with the European system. It is shown that the European beam gives better seeing along the centre of the road, and that straight ahead vision is similar with both types. A comparison of double-lamp dipping with single-lamp dipping adjusted to give equal forward horizontal intensity shows that seeing distances are very nearly the same even when one system faces the other, except that recovery from the minimum seeing conditions is more rapid when facing the single lamp. W. R.

612.843.367

172. Discomfort glare and glare factor calculation.

P MEAKER, *Illum. Engng.*, **50,** 82-85 (*Feb.*, 1955).

Describes by means of a worked example how the Harrison-Meaker Glare Factor Method can be used to determine the glarefactor applicable to an artificial lighting installation. Candlepower distribution data are required for the type of luminaire being considered. Luckiesh and Guth's (1949) discomfort glare results are used to allow for the effect of luminaire position. Numerous short cuts are possible when dealing with a large installation. P. P.

LAMPS AND FITTINGS

173. Fluorescent lamp candelabras. 621.329

E. BEVERUD, *Ljuskultur*, **27,** 18-20 (*Jan.-Mar.*, 1955). *In Swedish.*

Different forms of new vertical-mounting fittings called "Lysrörskandelabrar" for fluorescent lamps have been designed specially for the lighting of wide streets, public parks, recreation grounds and other open spaces. Each unit consists of a conical-shaped plastic body which can include up to sixteen 40-watt fluorescent tubes. R. G. H.

621.327.4

174. Electric discharge lamps in street lighting service.

J. W. YOUNG, *Illum. Engng.*, **50,** 19-26 (*Jan.*, 1955).

Discusses the relative operating characteristics of mercury vapour and incandescent tungsten lamps when used for street lighting, with brief references to fluorescent and sodium lamps when used for similar applications. The superior luminous efficiency and life of mercury vapour lamps over their incandescent equivalents are clearly demonstrated. The warm-up period and the influence of burning position on the ratings of mercury vapour lamps are referred to. Some comparisons of operating costs are given. P. P.

628.971

175. A review of recent additions and improvements to South African marine navigational aids.

E. C. LODGE, *Trans. S. African Inst. Elect. Engrs.*, **45,** 327-344 (*Nov.*, 1954).

Although primarily a review of the modernising of lighthouses, automatic lights and light and bell buoys around the coast of South and South-West Africa, the development of a fluorescent lantern for use as a harbour entrance light is also extensively described. Towns are situated about the major South African harbours in such a way that at night the harbour lights are lost to the mariner in the background produced by the city illuminations. A new design of harbour light has been tried out comprising eight 8-ft. cold cathode fluorescent lamps mounted vertically in front of a white-painted reflector. Although having approximately the same intensity (2,000 candelas) as the acetylene gas light formerly used, its effective range is considerably greater. A number of explanations for this improvement are offered. P. P.

LIGHTING

628.972

176. Lighting for visual performance in a TV set assembly plant.

R. M. SMART and W. ALLPHIN, *Illum. Engng.*, **49,** 567-571 (*Dec.*, 1954).

Describes the artificial lighting installation in a new television set assembly plant, and in particular the attention which was given to the lighting of the assembly line due to the work being performed against an immediate back-

ground comprising the bright cadmium-plated chassis in which are reflected the diffused images of the overhead light sources. A luminaire comprising two continuous rows of twin 90-watt industrial fluorescent troughs mounted side by side, and shielded by a continuous run of white diffusing corrugated vinyl plastic, was specially designed for the purpose and gave 230-240 lm/ft² of illumination on the chassis with luminance ratios of the order of 4 : 1.

P. P.

628.971

177. Projector illumination with sodium lamps—Norrköping Harbour.

G. NILSSON AND G. LISS, *Ljnskultar*, **27**, 9-11 (*Jan.-Mar.*, 1955). *In Swedish.*

Sodium lamps in parabolic projectors, two projectors per fitting, have been mounted in groups of eight or ten on 100-ft.-high towers at 317 ft. spacing in the harbour area of Norrköping. The service illumination between towers after six months' service is 0.5 lm/ft², rising to 1.5 lm/ft², near the towers. Results of illumination measurements with various experimental reflector surfaces for the projector are given. R. G. H.

628.971.6

178. New lighting of a main traffic route (Värmdovägen).

S. SATTERSTROM, *Ljuskultur*, **27**, 12-14 (*Jan.-Mar.*, 1955). *In Swedish.*

A road carrying 16,000 vehicles per day and night has been lit with fluorescent units, three 90-watt lamps or two 90-watt per unit, mounted at 45 deg. to the plane of the carriageway, at a mounting height of 7.5 m. (c. 25 ft.) at 40 m. (c. 113 ft.) single side spacing. Special low temperature lamps are used, with no starting or noticeable running troubles with temperatures down to −18 deg. C. (0 deg. F.) R. G. H.

628.972

179. Lighting design and brightness patterns—a preliminary investigation.

H. E. BELLCHAMBERS AND K. R. ACKERMAN, Trans. *Illum. Eng. Soc. (London)*, **20**, (*No.* 2, 1955).

Analyses the chief factors in lighting design and the present state of knowledge and practice; describes an investigation into the illumination and brightness pattern of an interior, and presents a method of interior lighting design to provide desirable brightness patterns. Use is made of sector flux concepts for the calculation of direct light and model studies for the calculation of inter-reflected light. The application of the method to a school classroom is shown in detail. Further model studies are stated to be necessary to produce the general reference tables required for more generalised application of the method. W. R.

180. Dock lighting problems. 628.971

W. A. KRAUSE, *Lichttechnik*, **7**, 45-49 (*Feb.*, 1955). *In German.*

The material used for this paper was collected for the report on railway and dock lighting to be presented to the C.I.E. It refers specifically to installations at Hamburg, but the principles are of universal application in docks. One of the most important is the necessity for avoiding any glare to navigators, either direct or by reflection in the water. Quayside lights are therefore carefully shielded to prevent any spill over the edge of the quay. They are frequently mounted on the shed wall. The use of fluorescent lamps for shed lighting, in passenger and Customs halls and on roadways is increasing and a new type of fluorescent lighting fitting for the roadways in dock areas is shown. Crane lights, including the cluster lights used to illuminate a ship's hold during loading or unloading, are described. There are some impressive photographs of the new installations at Hamburg. J. W. T. W.

628.971

181. Safety and visibility by daylight in under-passes.

H. LOSSAGK, *Lichttechnik*, **7**, 49-53 (*Feb.*, 1955). *In German.*

This paper is concerned with short tunnels or underpasses such as are common where a road passes beneath a railway with a number of tracks side by side. The problem of visibility in such tunnels is examined and it is pointed out that objects can easily disappear against the walls, owing to the high brightness of the tunnel exit seen by a driver. The advantage of having openings to admit daylight at intervals along the tunnel is shown by reference to the illumination curves for particular examples. The comparative inefficiency of ordinary artificial light sources is clearly seen. A broad horizontal band of white tiles on the tunnel wall is valuable and retroreflectors could also be used with advantage. J. W. T. W.

628.972

182. Importance and significance of the daylight factor in school lighting.

G. FESEL, *Lichttechnik*, **7**, 18-20 (*Jan.*, 1955). *In German.*

This thesis by an architect takes the daylight factor as the starting point in the planning of daylight in a school classroom. A diagram is given to show for what periods of the day (on the average) at different times of the year a given outdoor illumination may be expected and the corresponding indoor illumination for a specified value of daylight factor. The author compares the recommendations of codes published in different countries and discusses the implications of the values specified. In his summary he takes 2 per cent. as the minimum value for the daylight factor at any place of work in a classroom and 12 lm/ft² as the minimum illumination, artificial lighting being required if the daylight illumination falls below this value.

J. W. T. W.

628.973

183. Utilisation factors and room efficiency factors.

R. G. WEIGEL, *Lichttechnik*, **7**, 13-17 (*Jan.*, 1955). *In German.*

A utilisation factor is the product of the light output ratio of the fittings used and a factor determined by the room dimensions and decoration. This paper is concerned with the latter factor (called the room efficiency factor) and shows how it may be affected by the shape of the room and the number, arrangement and distribution of the fittings. The author has compared the data from various sources and has arrived at a series of diagrams in which the room efficiency factor is shown as a function of the room dimensions for direct, general-diffusing and indirect systems, and for light-tone, medium-tone and dark rooms. The function of the dimensions is b/h for direct lighting, where h is the mounting height, and b/H for the other systems, where H is the ceiling height. In each case b is the length of the side of a square room and a simple function of length and breadth for other rooms. J. W. T. W.

184. Lighting installation in the central control room of Orebro power station.

O. BLOMQWIST, *Ljuskultur*, **27**, 15-17 (*Jan.-Mar.*, 1955). *In Swedish.*

A luminous ceiling has been installed in an attempt to create a "daylight environment" without direct glare or reflected images on the vertical control panels. Spaces behind the control panels are lit by inset fluorescent luminaires. The luminous ceiling operates from two separate starting circuits. The illumination levels are 35 and 20-25 lm/ft² respectively on the control table and the control panels. R. G. H.

Trade Notes

The corporate name of THE F. W. WAKEFIELD BRASS COMPANY, Vermilion, Ohio, has been changed to The Wakefield Company. General Manager A. F. Wakefield gave two reasons for the change: the fact that his father, F. W. Wakefield, who founded the company in 1907, has long been deceased; and the fact that the word "brass" has been misleading. Though the original Wakefield lighting equipment was built largely of brass, the modern operation uses hardly any. Furthermore, the inclusion of "brass" in the company name brought inquiries from companies wanting quotations on brass for fabrication. There is no change in the name of the Canadian subsidiary, WAKEFIELD LIGHTING LIMITED, London, Ont.

THE B.T.H. CO. LTD. announce a price reduction in their range of "Monolux" bare lamp batten fittings. A "Monolux" 5-ft. 80-watt fitting now costs £5 15s. 8d., and the "Monolux Junior" (4-ft. 40-watt) costs £5 5s. 0d. Previous list prices were £6 10s. 0d. and £5 6s. 8d. respectively.

THE EDISON SWAN ELECTRIC CO., LTD. announce price reductions for their 5-ft. 80-watt and 4-ft. 40-watt fluorescent lighting fittings, LS. 1874 and LS. 4007. The 5-ft. fitting with switch start gear is reduced from £6 10s. 0d. to £5 15s. 8d. and the 4-ft. fitting from £5 6s. 8d. to £5 5s. 0d.

METROVICK 5-ft. 80-watt (3794) and 4-ft. 40-watt (3814) streamlined batten fluorescent fittings with switch start control gear have been reduced in price to £5 15s. 8d. and £5 5s. 0d. respectively. With instant start gear (220/250-volt) the fittings now cost £6 19s. 4d. and £6 5s. 8d. respectively.

THORN ELECTRICAL INDUSTRIES LTD. announce that as from June 1 the prices of their commercial glassware are reduced. At the same time there will be an alteration in the trade terms.

EKCO-ENSIGN ELECTRIC LTD. also announce reductions in prices and discounts policy applying to their diffusing glass fittings for use with tungsten lamps as from June 1.

PHILIPS ELECTRICAL LTD. announce the formation of a London and Home Counties Region which will be concerned with the marketing of all products of the company. It comprises the S.E. section of the country, bounded roughly in the north by the Wash, by the Oxfordshire/Worcestershire border in the N.W., and in the S.W. by Southampton. The area also includes the Isle of Wight and the Channel Islands. Mr. Hector M. Thorne has been appointed general regional manager of the London and Home Counties Region. Mr. S. Poole has been appointed regional manager of Lighting and Electrical Appliances Division.

As a result of improving performance during the last 12 months revised efficiencies for all sizes of White 3,500 deg. K. and Daylight fluorescent lamps are announced by THORN ELECTRICAL INDUSTRIES LTD. and EKCO-ENSIGN ELECTRIC LTD. The increases vary between 5 and 12 per cent. The 80-watt White lamp now has an average light output through 5,000 hours' life of 4,160 lumens, and the Daylight lamp 3,920 lumens.

The ELECTRIC LAMP MANUFACTURERS' ASSOCIATION announce that the list prices of some of the more popular vehicle bulbs are being reduced in the order of 10 per cent. as and from June 1. These reductions are made possible by a greater degree of standardisation of types and an increasing overall demand. The resulting improvement in productive efficiency has offset the increasing costs of labour and raw materials.

Obituary

ANDRÉ CLAUDE

It was with deep regret that we learned of the death on May 13, at the age of 55, of André Claude, President of Claude-Paz et Silva, of Paris.

After graduating at the Ecole de Physique et Chimie Industrielle in Paris in 1923, André Claude joined the family business as assistant to Georges Claude. In 1928 he took over responsibility for the development of neon tubing and signs, building it up into the business which is now known internationally.

He carried out much important fundamental research on the rare gases and light sources; in addition to work on both cold and hot cathode fluorescent lamps he also worked on the production of xenon and krypton gases and their use as fillings in incandescent lamps. In recent years he and his organisation played a leading part in the development and use of colour corrected mercury lamps in France.

He had a great flair for the decorative aspects of lighting; he lectured on this subject to the I.E.S. Summer Meeting in 1954, when all who met him were impressed by his personality and knowledge.

He was a man of boundless energy. The inspiration he gave his colleagues was returned by their loyalty and devotion. In addition to his connections with the family business he was also a director of Claude-General Neon Lights Ltd. of England, a past-president of the Association Française des Eclairagistes and an officer of the Legion d'Honneur.

By his death France has lost a great industrialist and the lighting industry one of its outstanding personalities. He will be remembered by all who met him or who came into contact with his work as a man of great sensibility and of great heart.

GEOFFREY F. FALK

It is with deep regret that we report the death of Geoffrey F. Falk, T.D., M.I.E.E., a director of Falk, Stadelmann and Co. Ltd., suddenly on Tuesday, May 24.

Mr. Falk was educated at University College School, Repton, and at Faraday House. He was commissioned in 1918 in the Wiltshire Regiment, and after the war he served in the Territorial Army in the Manchester Regiment. On the outbreak of the 1939 war he rejoined the Second London Divisional Signals, becoming Lieut.-Colonel and C.S.O. of the South Eastern Command and Northumbrian District and B.A.O.R. He joined Falk, Stadelmann and Co. Ltd. in August, 1922, was appointed local director in September, 1943, and became a full director in January, 1947.

JOHN H. PARKER

It is with regret that we report the sudden death on May 15 of John H. Parker, South Wales Manager of Hartley Installations Ltd. Mr. Parker, who was aged 46, was a founder member of the Swansea Group of the I.E.S. and a past chairman.

Personal

Claude-General Neon Lights Ltd. announces that MR. E. J. SHUTER has rejoined the company as London sales manager.

MR. FRANK J. HAWKINS recently retired from the B.T.H. Co. Ltd. after 45 years of service with the company. The B.T.H. Co. Ltd. also announce the appointment of MR. A. B. FROST as manager of their Northampton lamp depot. MR. FROST, who succeeded MR. F. E. PERRY on May 1, has been with the company at Cheltenham, Birmingham and Wolverhampton since 1939. MR. PERRY leaves the

B.T.H. Co. Ltd. after 28 years to take up an important appointment with E.M.F. Ltd., Northampton.

MR. V. C. H. CREER, of the B.T.H. Co. Ltd., has been re-elected chairman of E.L.M.A. for the year commencing June 1, 1955.

MR. L. A. FICKLING, sales manager of Linolite Ltd., left Southampton on June 23 to visit Cape Town, Durban, Johannesburg and Salisbury. He will be holding trade shows for wholesale distributors and others interested in modern domestic and commercial lighting, returning on August 19.

Holophane Ltd. announce the following board rearrangements and appointments which will take effect on July 1, 1955. MR. GUY CAMPBELL has resigned his position as joint managing director, but will remain chairman of the company. DR. S. ENGLISH has resigned from his position as joint managing director and also as technical director, but will remain on the board and has been appointed vice-chairman. MR. C. H. BANSBACK (secretary) and MR. W. T. SOUTER have been appointed joint managing directors and MR. J. G. HOLMES joins the board as technical director.

Situations Vacant

Lighting Fittings, DRAUGHTSMAN required. Interesting and varied work in special fittings or Junior for training. Write: George Forrest and Son Ltd., 30, Osborne Road, Acton, W.3.

ASSISTANT ILLUMINATING ENGINEER required by lighting fittings manufacturer in Home Counties, able to prepare interior lighting schemes and advise on fittings, estimate prices and prepare quotations. Apply giving age, experience and salary required to Box No. 893.

A leading firm in the lighting industry has a vacancy for a first-class DESIGNER in its lighting department. Work will be concerned with special decorative fittings designs in both contemporary and traditional styles, and new lighting developments. The post offers attractive prospects and salary for man with initiative, imagination, and a sound experience in this field. Apply in writing, quoting Ref. D.O., to the Staff Manager, The General Electric Co. Ltd., Magnet House, Kingsway, London, W.C.2.

STREET LIGHTING ENGINEER ASSISTANT to help in the development and application of a wide range of street lighting equipment. Excellent opportunity for a young man with initiative. Write giving details of qualifications and salary required to Box No. A153, c/o Central News Ltd., 43, London Wall, E.C.2.

STREET LIGHTING SALES ENGINEER required for well-known lighting organisation in London. Sound street lighting technique and experience in the sale and application of street lighting equipment essential. Applications, giving details of age, education, experience and salary required, to Box No. A157, c/o Central News Ltd., 43, London Wall, E.C.2.

Crompton Parkinson Limited require JUNIOR LIGHTING ENGINEER, City and Guilds Inter-Illumination standard, for London Planning Office. Write stating age, experience, salary required, etc., to Ref: MD/P2, Crompton House, Aldwych, London, W.C.2.

WANTED: SALES REPRESENTATIVE to market well known design of light fittings. Only persons with initiative and self reliance need apply to Box No. 894.

Intelligent young ASSISTANT required for Lighting Engineer in London Office. Work mainly on drawing board and handling simple enquiries. Please send all details, in confidence, to Box No. 895.

A leading electrical and electronic engineering Company in London wish to fill the following Drawing Office vacancies:—(a) COMPONENTS DRAUGHTSMAN with O.N.C. standard education and experience in radio or light mechanical engineering. (b) LIGHTING FITTINGS DRAUGHTSMAN with experience of sheet metal work, lighting design and electrical wiring. For both positions training will be given and young men with useful but not related experience will be considered. In addition to good starting salaries, the Company offers excellent staff conditions, pension scheme, canteen, etc. Apply to Personnel Officer, Century House, Shaftesbury Avenue, London, W.C.2. Telephone No. Gerrard 7777.

Electric Lamps—Manufacturers in East Midlands area have vacancy for EXPERIENCED FOREMAN to take charge of the production of all types of discharge lamps. Excellent opportunity for experienced and energetic man. Superannuation Fund, canteen, social club, etc. Apply, giving full particulars of training, experience, age, etc., to Box No. 898.

The British Thomson-Houston Company, Ltd., have a vacancy in their research laboratory at Rugby for a qualified PHYSICIST or ENGINEER for radiation measurements in a lamp development group. The work is varied and interesting, and offers scope for development of new techniques. Applicants are invited to send particulars of their age and qualifications to the Director of Research, British Thomson-Houston Co., Ltd., Rugby, quoting reference RM.

Leading manufacturers require ASSISTANT for the technical department of their Manchester branch office. Applicants preferably with O.N.C. and some practical electrical experience. Box No. 897.

Lighting Fittings. Leading manufacturers of fluorescent lighting fittings have a vacancy for a DRAUGHTSMAN with experience of the design and production of high-class fittings. Excellent conditions and prospects. Superannuation Scheme. Apply to Personnel Officer, Crompton Parkinson, Ltd., Doncaster, Yorks.

Physical Society Exhibition

(*Continued from p.* 244)

maker had his own recipe and when anyone else tried to prepare a phosphor according to prescription he was quite likely to be unsuccessful. So far, he said, there was no phosphor which would emit red light by electro-luminescence, but he showed examples of blue, green and yellow phosphors.

The phosphors used in fluorescent lamps, said Dr. Garlick, were of great scientific interest because they contained a double activator. One provided an absorption band at the 2537 line of the mercury discharge, while the other provided an emission band in the visible. He showed an array of these doubly activated phosphors, the calcium halophosphates, with different proportions of the halogens and different amounts of the two activators.

In the final section of his lecture Dr. Garlick described work in progress at Birmingham University on the production of phosphors which would emit strongly in the infra-red. The first phosphor of this kind was developed in Russia and was of cuprous oxide. This had a maximum emission at about 1 μ. Next to be developed were a series of lead sulphide phosphors with different activators, and zinc sulphide activated with cobalt. These had maxima of emission at various wave-lengths in the infra-red, ranging as far as 4 μ and Dr. Garlick demonstrated their behaviour by causing the radiation from them to fall on a cell sensitive to wave-lengths in this region. He mentioned some of their possible applications.

POSTSCRIPT By "Lumeritas"

Four years ago no fewer than 24 Marine cadets were killed by a bus on a dark road in a North Kent town. It was a tragedy which shocked the whole country and readers will doubtless remember the evidence as to bad street lighting which was given at the inquiry into the cause of the accident. Quite a long time afterwards the correspondence columns of this journal included a letter from Mr. A. Cunnington who, happening to visit the town in question, was much surprised to find that no adequate improvement of the street lighting had been made. Now, at last, extensive relighting of the town has been carried out and, according to the borough engineer, Dock Road —where the disaster occurred—is among the brightest and safest streets in the town, the new lighting being of "the highest possible standard." There is much relighting of streets going on up and down the country—scarcely a week passes without reports in local newspapers of schemes authorised, in progress or completed. This is good, and it is encouraging to know that investigations made by the Road Research Laboratory—reported to the C.I.E. at Zürich last month—have shown that, on the whole, better street lighting tends to be associated with fewer night accidents. On roads with good lighting accidents appear to be about 25 per cent. less frequent than on comparable roads with poor lighting.

Besides the use of fluorescent light for chitting early seed potatoes, which I mentioned in May, experiments are going on with flash lighting of poultry as a means of increasing the yield of eggs. Instead of adding to the daily hours of lightness by using ordinary artificial lighting when natural light of sufficient intensity is not available, intensive flashes of light are given at certain times during the night. Both methods of artificial lighting do increase egg production but, so far, it is uncertain whether flash lighting is more or less effective than continuous artificial lighting. The "forthright independent lighting authority"—whom I also mentioned in May—whimsically describes fluorescent lighting as "hammering on the retina" (although the normal fluctuations of light from fluorescent tubes, as well as from tungsten lamps, are imperceptible) and so, to be similarly picturesque in expression, I suppose flash lighting sledge-hammers the birds' retinae with light! In fact, because the flash method was once called "shock lighting," a daily newspaper erroneously reported that poultry were being given "electric shocks" to promote egg laying and so caused trouble between the experimenters and the R.S.P.C.A.! There is, of course, nothing harmful to the retina in fluorescent lighting, as the word "hammering" is intended to imply, and flash lighting, e.g., by lighthouses, is applied to some humans with beneficial results—although not yet with the aim of raising the birth rate!

Another recent application of flashing lights is to new British cars as an alternative to the more familiar semaphore-arm type of direction indicator. Now I have been, and am still, a staunch advocate of flashing beacons at uncontrolled pedestrian crossings, because these flashing lights are more conspicuous than continuous ones, especially in a multi-light environment, and their message is a very simple and straightforward one. But flashing car direction indicators are a very different "kettle of fish," at least as they are now fitted to most of the new cars. They are mounted too low and too close to the side and tail lamps. The front indicator lamps are less conspicuous than the older "carrots" both to vehicle drivers and to pedestrians but particularly to the latter (and in daylight) who are not constantly on the look-out for them. Their message, although less direct than that given by the pointing indicator, will doubtless become universally understood in time, but it will always be wasted when it cannot be seen. I am not, therefore, surprised that the Birmingham police are strongly in favour of the illuminated "finger" type of direction indicator, although the flashing lights mounted "amidships" at roof level on a number of London taxicabs are much better than the low-mounted built-in flashing indicators on private cars.

The chairman of the Radio Corporation of America has been forecasting radical changes in our methods of providing illumination in the not too distant future. "We are now engaged," he said, "in the development of a new form of light . . . electronic light will eventually provide startling substitutes for present types of illumination and thus will change the very appearance of our homes, stores, factories, streets and cities. Electric light will have been freed from the prison of the vacuum bulb. . . ." If this is a reference to electroluminescent light sources, there is less optimism in this country as to their general use if one may judge from the paper on this subject read to the I.E.S. in April by Messrs. Bowtell and Bate. These authors state that "when lamp research laboratories began, a few years ago, to take an interest in electroluminescence there was a tendency to think that this new method of producing light might become a worthy successor to fluorescent and filament lamps for general lighting purposes. After several years of research effort, however, the light output, loading and efficiency of the new source remain disappointingly low, and general purpose lighting by electroluminescence seems unlikely in the immediate future." Nevertheless, there are a number of applications for electroluminescence, some of which are mentioned by the authors cited.

According to a recent newspaper report, the Ministry of Transport has sent experts from the Fine Arts Commission to Chepstow to decide whether white or yellow street lighting is to be installed in this ancient town. It appears that the civic leaders and the traders want white light and if the Arts experts agree that this is desirable then the Ministry will give a grant accordingly. If, however, the verdict is for sodium lighting the town will have to pay the extra if they want white. I assume that "white" means fluorescent in this case. The battle of the "whites" and the "yellows" is raging in a number of council chambers and, if the reported procedure of the Ministry is to be followed elsewhere, the experts of the Fine Arts Commission are in for a busy time.